THE JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

JUNE 1958

Volume 52, Number 3 Whole Number 432

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

NATIONAL OFFICERS AND COUNCIL FOR 1958

Honorary President—The Honourable W. J. DUNLOP, D.PAED., Minister of Education for Ontario.
President—HELEN S. HOGG, PH.D., Toronto.
First Vice-President—ANDREW MCKELLAR, PH.D., Victoria.
Second Vice-President—PETER M. MILLMAN, PH.D., Ottawa.
National Secretary—J. E. KENNEDY, M.SC., 252 College Street, Toronto 2B.
National Treasurer—J. H. HORNING, M.A., 252 College Street, Toronto 2B.
Recorder—FREDERIC L. TROYER, Toronto.
Librarian—J. B. OKE, PH.D., Toronto.
Council—Elective Members: MIRIAM S. BURLAND, Ottawa; A. VIBERT DOUGLAS, Kingston; CARL REINHARDT, Toronto; Past Presidents: R. M. PETRIE, Victoria; JOHN F. HEARD, Toronto.

Halifax Centre: Rev. M. W. BURKE-GAFFNEY, S.J., L. CARRIGAN (Pres.).
Quebec Centre: PAUL H. NADEAU, J. ALFRED DUMONT (Pres.).
Montreal Centre: G. HARPER HALL, A. R. MACLENNAN (Pres.).
Centre Français de Montréal: J. R. GRIGNON, JEAN ASSELIN (Pres.).
Ottawa Centre: J. L. LOCKE, J. E. LILLEY (Pres.).
Toronto Centre: MRS. K. M. HEATON, G. A. COOPER (Pres.).
Hamilton Centre: H. B. FOX, REV. N. GREEN (Pres.).
London Centre: W. G. GRAHAM, W. WEHLAU (Pres.).
Windsor Centre: ————————, E. W. KEITH (Pres.).
Winnipeg Centre: R. J. LOCKHART, J. SCATLIFFE (Pres.).
Edmonton Centre: E. S. KEEPING, EARL MILTON (Pres.).
Calgary Centre: ————————, WALTER H. STILWELL (Pres.).
Vancouver Centre: G. M. SHRUM, R. J. CLARKE (Pres.).
Victoria Centre: R. S. EVANS, N. G. ROGERS (Pres.).

PRINTED IN CANADA
BY THE UNIVERSITY OF TORONTO PRESS

THE JOURNAL OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

Vol. 52, No. 3 JUNE 1958 Whole No. 432

GLOBULAR STAR CLUSTERS*

By Helen Sawyer Hogg
David Dunlap Observatory, Richmond Hill, Ontario

In the limited time available for my address on globular clusters, obviously I cannot cover the whole of such a large field. So I shall discuss several of the more significant advances made in the last decade in our knowledge of globular clusters, assuming that you are familiar with the characteristics of these beautiful objects.

You know that they are huge and massive satellite systems of our galaxy, composed of thousands to hundreds of thousands of stars. They are at distances of thousands of light-years from us, with linear diameters of a hundred light-years or more. The distances are determined from the apparent magnitudes of the brightest stars, whose absolute magnitudes may be known from the colour-luminosity diagram, or from the presence of RR Lyrae variables, of mean absolute magnitude zero. The apparent magnitudes must be corrected for interstellar absorption, from the selective reddening or colour-excess determined by Stebbins and Whitford (1936). Some clusters close to the galactic plane are strongly reddened, and the computed distance may have a wide spread depending upon the correction applied.

Numbers. Most of the bright globular clusters were catalogued in the eighteenth century by the famous French observers, Messier and Méchain, and all but a few were included in the New General Catalogue of Dreyer, with its supplements. The number of globular clusters recognized in our galaxy has increased rather slowly, but it is now 70 per

*Parts of this paper constituted the Presidential Address delivered at the At-Home of the Royal Astronomical Society of Canada at McMaster University, Hamilton, Ont., March 28, 1958.

cent. greater than the 69 classed as globular by Shapley (1918). My current catalogue lists 119. The study of Edmondson (1935) on the total mass of globular clusters from their motions indicates that 200 may be associated with our galaxy, while estimates by de Kort (1941) run

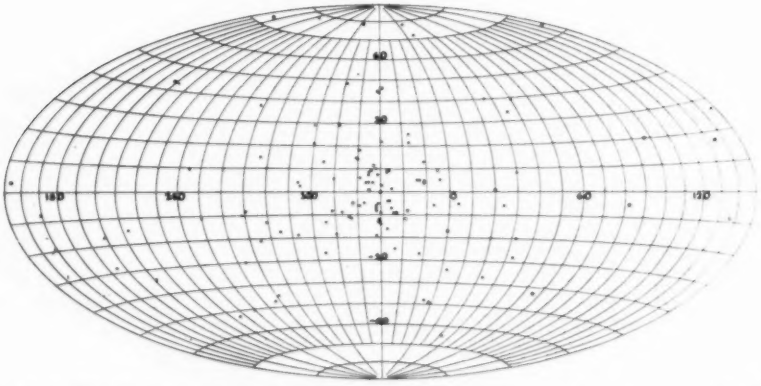


FIG. 1—Distribution of 119 globular clusters in galactic co-ordinates on an Aitoff projection. Open circles represent clusters added to the globular list since 1948.

as high as 2,000, depending on the assumption made for the concentration of mass to the galactic centre.

Of the more recent additions to the globular cluster list, several are moderately bright objects, like NGC 2158, 6838, and 7789, previously considered to be galactic clusters. The majority, however, are faint, low luminosity objects. Fourteen new globular clusters have been found as a result of the National Geographic-Palomar Sky survey with the 48-inch Schmidt (Abell, 1955). Of these, 12 are new objects not previously catalogued. By comparison with the great Messier 13, the rich Omega Centauri, or the luminous 47 Tucanae, some of these recent objects look pathetic. Even long exposures with great telescopes like the David Dunlap Observatory 74-inch do not show many stars. Some of them, like IC 1276 which is under investigation with this telescope, and in which one variable has been noted already, are in regions of strong obscuration. They are therefore not at great distances, relatively speaking, though the magnitudes of the individual stars are faint, in the 18th magnitude.

Others are in regions notably free of obscuration, at distances so great that they must be considered intergalactic. The cluster NGC 2419 has been

known as an "intergalactic tramp" ever since Baade (1935) determined the enormous distance for it of 55.8 kpc. from the sun, 64.3 kpc. from the centre of the galaxy. This is so much greater than any accepted dimension for our galaxy that it seems to leave NGC 2419 suspended in space.

Recent explorations of the faint new clusters now indicate several such tramps. Distances have been determined for three of these new clusters, as indicated in the accompanying table. They have moduli

INTERGALACTIC STAR CLUSTERS OF OUR GALAXY

Name	Const.	R.A. 1950	Dec.	l	b	Ang. Diam.	Meas. Mod.	Corr. Dist. kpc.	Pg. Mag. Br. Stars
		h m	° ′	°	° ′				
NGC 2419	Lyn	07 34.8	+39 00	148	+27 7.2	19.22	55.8		17.84
Pal. 3	Sex	10 03.0	+00 18	209	+43 2.2	20.6	130		19.5
Shak.	UMa	10 52.0	+40 44	143	+64 1.3	20.6	130		19
Pal. 4	UMa	11 26.6	+29 15	170	+73 1.5	20.2	98		19

of the order of 20 and distances of the order of 100 kpc. Palomar no. 3, a faint system in Sextans announced by A. G. Wilson (1955), was reported on by Burbidge and Sandage (1957) at the December meetings of the American Astronomical Society. The colour-magnitude diagram of its brightest stars, whose magnitudes are 19.5, gives a modulus of 20.6 or a distance of 130 kpc. These same observers have determined a modulus of 20.5 for Palomar no. 4, discovered by Hubble in Ursa Major, and investigated by van den Bergh (1956). Rosino (1957) of Asiago has found two red slow variables in this cluster. From them he derived a modulus of 20.2, distance 98 kpc. Meanwhile Shakhbazian (1957) has reported on a new globular cluster found by Ambartzumian from the Palomar Sky Atlas charts. From measures of the red and blue magnitudes on the Palomar prints, he finds a modulus of 20.6, distance 130 kpc., for this cluster, which is also in Ursa Major. It has an estimated total visual absolute magnitude of —5.6, which places it near the lower end of the luminosity scale for globular clusters. These recently-discovered objects emphasize once again the fact that we are much quicker to learn about the bright objects in our universe than about the faint ones.

Relation of globular clusters to elliptical galaxies. These globular clusters scattered at great distances from our galaxy logically raise again the

old question first asked by Lundmark (1930)—"are the globular clusters and the anagalactic nebulae related?" In appearance many of the elliptical galaxies look like a giant-sized version of a globular cluster. Is it possible that the two types of objects are the two ends of a sequence, and that some day we may find intermediate forms?

The present evidence is against such a relationship. The fundamental differences between globular clusters and elliptical galaxies seem too great to be bridged, though the problem has recently been raised again for the luminous globular cluster 47 Tucanae. Gascoigne and Burr (1957) have shown that a plot of the logarithm of the surface brightness against the fourth root of the radius for this cluster resembles that for elliptical galaxies, but the central brightness is not so high. According to Baade, the linear diameters of elliptical galaxies are of the order of a thousand parsecs or more, while that of the largest globular cluster is only a

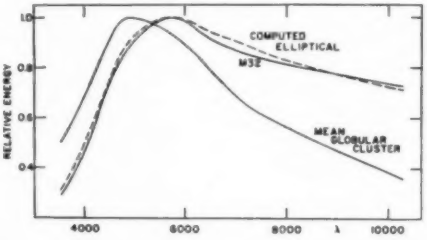


FIG. 2—Relative spectral energy-curves for a mean globular cluster and M 32. The dashed line is a similar curve obtained for the computed elliptical nebula (Roberts, 1955).

hundred parsecs. M. S. Roberts (1956) has constructed a spectral energy curve for elliptical galaxies which shows that they are redder than globular clusters, and presumably have relatively more of the fainter stars. The ratio of solar masses to the total luminosity (in solar units), called a mass-luminosity ratio, is much higher for the elliptical nebulae. Schwarzschild (1954) derived a ratio of 200 for M 32, and 100 for NGC 3115, both elliptical galaxies, while O. C. Wilson and Miss Coffeen (1954) obtained a ratio of 2 for the cluster M 92.

Clusters in Extra-galactic Systems. While we are far out in space, before we swing back to some of the nearer globular clusters, let us take a swift glance at those belonging to other galaxies. We will not attempt to total these clusters, because Baum (1955) reports that one galaxy, M 87 (NGC 4486), a giant E0 nebula in Virgo, has more than one thousand globular

clusters associated with it. The new Lick 120-inch telescope is to be used to measure magnitudes in two or more colours for the clusters in M 87. Baum has already compared these globular clusters photometrically with those in Messier 31, and derived a modulus of 30.2 for the Virgo cluster of galaxies.

The Large and Small Magellanic Clouds together yield hundreds of clusters, as does M 31 in Andromeda. Precise colour work is needed to show which clusters are a globular type, and which galactic. Even colours may not be an absolute criterion as blue globular clusters are frequent in both Clouds. According to de Vaucouleurs (1956) 37 per cent. of the globulars measured in the Small Cloud are blue and 54 per cent. in the Large. This is a real singularity since only two, NGC 2419 and NGC 7492, have been noted in our galaxy, and they are rare or absent in M 31. In that system, however, the interstellar dust is known to redden the colours. According to Kron and Mayall (1955) photo-electric magnitudes in two colours have now been obtained for 102 extra-galactic globular clusters in M 31, NGC 185 and 205, M 33, and the Fornax cluster and the two Magellanic Clouds.

A fascinating aspect of the study of globular clusters belonging to other galaxies has been the discovery at the Radcliffe Observatory, Pretoria, of variable stars in the cluster NGC 121 on the outskirts of the Small Magellanic Cloud. In the immediate region of this cluster, nine variables have been found, of which five are in it. Furthermore, Thackeray has now derived periods of these five, in a paper now in press. Two of them are among the reddest and brightest of the cluster stars, with periods of 140 and 112 days. Three are RR Lyrae stars with periods between 0.50 and 0.64 day. These variables are around 19th magnitude, but accurate magnitude sequences in the Cloud are still to be obtained for the faint stars. This is a new step into distant space—the study of individual stars in globular clusters belonging to other galaxies.

Star Counts. With the great power of the 200-inch Hale telescope it is now possible in globular clusters to work with stars as intrinsically faint as our sun. Sandage (1953, 1955, 1957) has made a count of 44,540 stars in the globular cluster M 3. From this he has derived the luminosity function of this cluster to absolute visual magnitude 6.0. At the break-off point in magnitude, the function is still rising. An application of various luminosity functions to the observed counts leads to an estimate of 588,000 stars in M 3. The function adopted requires that 48,500 white dwarfs are present in the cluster, with a mass of 69,900 suns. The total mass of the cluster is 245,000 suns. Whereas half the total light of M 3

comes from stars brighter than zero absolute magnitude, half the mass is contributed by stars fainter than +11.

Colour-magnitude diagrams. The unusual type of colour-magnitude diagram which the globular clusters present was first noted by Shapley (1915) when he showed that in M 13 the brightest stars are red, not blue, and that other globular clusters had stars whose absolute luminosity increased with increasing colour. Later ten Bruggencate (1927) emphasized this point, but only after Baade resolved the nucleus of the Andromeda galaxy and differentiated between stellar populations I and II, was the importance of this difference universally recognized. The colour-magnitude diagram of a cluster provides an excellent criterion between globular and galactic.

In recent work, accurate diagrams involving thousands of stars, have been determined for eight globular clusters. The most complete determination so far is for M 3, but the comparable diagram was obtained to M_{pv} +4.4 for M 92 by Arp, Baum, and Sandage (1953). Diagrams are available also for M 2, M 5, M 10, M 13, M 15, and NGC 4147. In M 13 Baum (1954) has measured stars of magnitude 23.8 with the new photon-counting photometer at the prime focus of the 200-inch. The main sequence in M 13 seems to lie two magnitudes below the ordinary main sequence for the solar neighbourhood, while the colour-magnitude diagrams for M 92 and M 3 fall in between. This raises the problem of whether the main sequence is unique, or whether there may be a whole band of possible main sequences whose positions depend on chemical abundances.

Evolution. A great significance of the colour-magnitude diagrams of clusters is the light that they can throw on the evolutionary tracks of stars. It is assumed that at some initial epoch all stars in the cluster were on the main sequence. They were chemically homogeneous, with none of their hydrogen converted to helium. As the stars begin to age, their initial hydrogen content is decreased, their helium increased, and eventually an isothermal core exhausted in hydrogen is formed. The details of the track may be computed for various intervals. In such an evolving system of stars the main sequence will then appear with a different slope from the original main sequence. The turn-off point from the original may be used to estimate the age of the cluster, as shown in the diagram by Sandage (1957). The ages of globular clusters are of the order of 6×10^9 years.

Spectra. The spectra of stars in globular clusters show marked differences

compared with those in galactic clusters or the solar neighbourhood. Pease (1914) pioneered in this work at Mount Wilson, with exposures up to 30 hours to obtain spectra in M 13. In the same cluster Lindblad

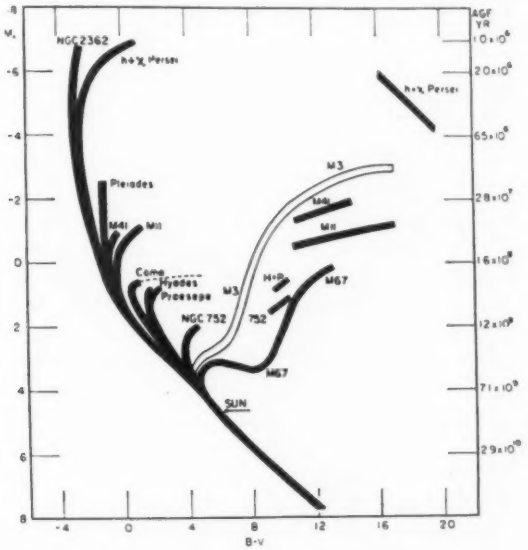


FIG. 3—A composite colour-magnitude diagram illustrating evolution in the galaxy (Sandage, 1957b). The departure of each cluster diagram from the main sequence near its termination point is an effect of evolution.

(1922) first drew attention to the weakness of the cyanogen absorption in three supergiant stars about spectral type K0. More recently Popper (1947) obtained precise spectral classifications for 14 stars in M 3, and 21 in M 13. The brightest stars are of spectral type G5-K0, luminosity class Ib, absolute photovisual magnitudes between -2 and -3, and colour indices between $+0.9$ and $+1.6$. Each cluster has at least one O- or B-type star amongst its brightest members. The cyanogen absorption to the violet of λ 4215 is weak.

This problem is now under intensive investigation by observers at Mount Wilson and Palomar, Deutsch (1955) Baum, and O. C. Wilson. Baum has shown that two red giants in M 3 and two in M 92 have spectral types far earlier than would be predicted from their colour. For example, in M 92 an F5-type star has a colour class for K3. Using ratios of lines of iron and chromium, Keenan classified the star as G3.

The integrated spectral types of globular clusters, first studied by Miss Cannon, have now been determined by N. U. Mayall (1946) for fifty clusters. As a test of the value of integrated spectra, the best Lick spectrogram gives an estimated value of F2 for M 13, in good agreement with the F0 average obtained by Pease from individual spectra. For the fifty clusters the spectral types are in the interval from A5 to G5 with the majority between F8 and G5, and average type F7.6 $\pm$3.6 p.e.

Mayall called special attention to a group of 10 clusters near the galactic centre which average type G2. Recently Morgan (1956) photographed the spectra of 12 clusters, including this group, with the 82-inch McDonald reflector and Cassegrain spectrograph, with a dispersion of 150 A./mm. from Hβ to Hϵ, and applied his two-dimensional classification methods. For nine clusters the spectra match closely with subdwarf F Stars, with a low relative abundance of metals to hydrogen, of the order of F-type subdwarfs in the solar neighbourhood. For three clusters, NGC 6356, 6637, and 6440, however, a surprising result is obtained. They have a more nearly normal abundance of metals. For NGC 6356 it even approaches that of the sun. Morgan concludes that the spectra of these three clusters are so different from the others that it is difficult to see how the stellar constitution can be similar. With our present ideas of relation of content of elements of high atomic number to the age of the material forming the star, do these observations indicate that not all globular clusters were formed in the early stages of our galaxy?

Variables. The field of variable stars in globular clusters is the one in which I have been primarily interested for more than a quarter of a century, and where I have been fortunate to have the light-gathering power and large scale of the two great Canadian reflectors. The stars in globular clusters are so faint and so crammed together that big telescopes are necessary for this work.

In this paper I will set down a few of the pertinent facts collected for my report on this subject for the next meeting of the International Astronomical Union in Moscow in August. When I started in this field 30 years ago, about 900 variables had been found in the 45 clusters then searched, out of 94 recognized as globular. However, definite periods were known in only 9 clusters (Shapley, 1930) for a total of about 475 periods. Most of these were in the clusters Omega Centauri, M 3, M 5, and M 15, all of which are outstandingly rich in variables, most of them RR Lyrae type. My last published catalogue (Sawyer, 1955) listed 1,421 variables in 72 clusters. Now 78 clusters have been searched out of the present total of 119, and over 1500 variables are known. Periods have been determined for 850 stars in 40 clusters.

It is not true, as once stated, that all globular clusters abound in variables. Only 7 clusters contain more than 50; three-quarters of the clusters contain less than 20. The most frequent number of variables

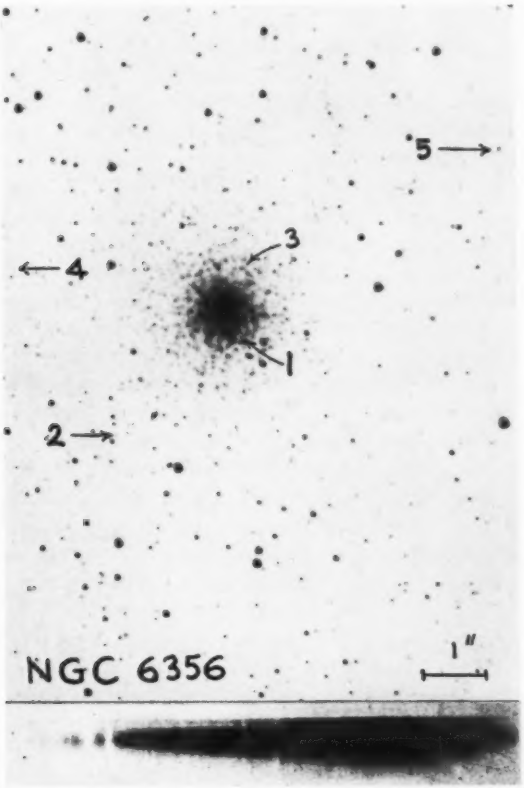


FIG. 4—*Above*: The globular cluster NGC 6356, photographed with the 74-inch David Dunlap Observatory reflector. Numbered stars are variables. *Below*: Spectrogram taken by Morgan with the 82-inch McDonald Observatory reflector, showing strong metallic lines.

found per cluster is one! Ninety per cent. of the variables appear to be RR Lyrae stars, with Bailey's types a, b, and c all represented. Schwarzschild (1940) has shown that stars in a particular region of the colour-magnitude diagram in a cluster are almost certain to be cluster-type variables. The frequency distribution of the RR Lyrae periods in a cluster is an interesting problem in itself.

Among the ten per cent. of variables not RR Lyrae type, almost all classes are represented—novae, Cepheids with periods to 10 days, Cepheids or W Virginis stars with periods from 10–26 days, long-period variables, eclipsing variables, W Ursae Majoris, SS Cygni, RV Tauri stars, and irregular and semi-regular of various sorts. No flare stars or R Coronae Borealis variables have yet been noted. It should be emphasized that this is a roster of variable types found within the optical boundaries of a cluster; not all of these variables will prove to be physical members of the cluster. Since globular clusters are one of the best examples of Type II population, a study of the types of variables they contain is obviously important.

The RR Lyrae stars are about the most reliable distance indicator available for globular clusters, according to present sentiment. They have a median absolute magnitude of 0.0. The longer period Cepheids in globular clusters are not so helpful. Few clusters have more than one or two, and in absolute magnitude they occupy a somewhat uncertain position well below the period-luminosity relation for Type I Cepheids.

I wish to remark here that the old notion no longer holds, that variable stars which are so numerous in globular clusters are absent in galactic clusters. Recent researches show the presence of T Tauri stars by the dozens or hundreds in clusters associated with nebulosity, like the Orion cluster; of eclipsing variables; and even of long-period Cepheids of Type I. A truer statement is that the types of variables differ between globular and galactic clusters, and that the type most frequent in the globular, the RR Lyrae, appears to be absent in galactic clusters.

Motions of globular clusters. The time interval is still too short for reliable information on motions to be gleaned from observed proper motions of these distant objects. Radial velocities from integrated spectra have been determined for at least 50 clusters, beginning with the pioneer work of V.M. Slipher (1918) with 10 clusters, and culminating in the extensive programme of Mayall at Lick, previously noted. The velocities range from −360 km./sec. to +291 km./sec. There is no appreciable deviation of the computed apex from the one generally assumed at galactic longitude 55° and latitude 0°. The solar motion with respect to the clusters is 175 km./sec., but allowance for observational selection would increase this to 200 km./sec., still substantially lower than the solar motion determined from other methods.

Using Edmondson's original method of analysing velocities, von Hoerner (1955) has tried to discover whether the clusters are travelling about the galactic centre in circular orbits or in orbits of such high

eccentricity that the motion is considered rectilinear. Von Hoerner concludes that most clusters now distant more than 14,000 pc. have rectilinear orbits, and that only about 30 per cent. of the nearer clusters can have circular orbits. Even the most remote globular clusters have periods of rotation around the galactic centre shorter than their ages. With a high percentage of rectilinear orbits, they must have passed through the galactic plane at least several times. At 50,000 pc. the period would be 2.5 billion years for a circular orbit or 0.9 billion for a rectilinear radial orbit. M 13, relatively near, would trace out a circular orbit in 200 million years or a rectilinear in only 70 million.

Otto Struve (1955) has done an interesting computation to show how far from the galactic centre the clusters were first formed. He used results by Lohmann (1953) that the linear diameters of globular clusters increase with distance from the galactic centre, not with distance from the sun. Clusters 25,000 pc. from the centre are about 30 per cent. larger than those at only 10,000 pc. By applying the probability of finding any given cluster at certain fractions of its apogalacticon distance from the centre, Struve finds that few if any clusters were actually born in the vicinity of the centre. Rather, the central region of the galaxy favoured the condensation of the stars which mould the central bulge, and the globular clusters were formed at great distances, up to 25,000 pc.

The globular clusters have retained their spherical states since their formation, according to von Weizsäcker (1955). On his theory, about 6×10^9 years ago, our galaxy was a roughly spherical cloud of turbulent gas with an admixture of dust grains. Gravitational effects caused the cloud to break up into smaller cloudlets. A density of 10^{-22} g./cc. is necessary to form the present population of stars in a globular cluster, but a higher one is indicated if a cluster has already lost a good share of its mass in passing through the dense clouds of the Milky Way. The globular clusters have reached a stage in contraction where they are so stable that their structures correspond to a solution of the equation for hydrostatic equilibrium (Finlay-Freundlich, 1947). This is why they appear so similar. If they differ only slightly in total mass and energy, there will be only moderate scatter in the values of their radii.

Globular clusters are dynamically so stable, so little affected by any disruptive forces, that their individual stars will die as stars before the clusters disintegrate as clusters.

References

Abell, G. O. 1955, *P.A.S.P.*, vol. 67, p. 258.
Arp, H., Baum, W. and Sandage, A. R. 1953, *A.J.*, vol. 58, p. 4.
Baade, W. 1935, *Mt. W. Cont.*, no. 529.

Baum, W. A. 1954 *A.J.*, vol 59, p. 183; 1955, *P.A.S.P.*, vol. 67, p. 328.
van den Bergh, S. 1956, *P.A.S.P.*, vol 68, p. 449.
ten Bruggencate, P. 1927, "Sternhaufen", Berlin.
Burbidge, E. M. and Sandage, A. R. 1957, *A.A.S. Abstract of Papers*, December.
Deutsch, A. 1955, "Principes Fondamentaux de Classification Stellaire", Paris, p. 25.
Edmondson, F. K. 1935, *A.J.*, vol. 45, p. 1.
Finlay-Freundlich, E. 1947, *R.A.S., M.N.*, vol. 107, p. 268.
Gascoigne, S. C. B. and Burr, E. J. 1957, *R.A.S., M.N.*, vol. 116, p. 570.
von Hoerner, S. 1955, *Z. f. Ap.*, vol. 35, p. 255.
Kron, G. E. and Mayall, N. U. 1955, *P.A.S.P.*, vol. 67, p. 326.
de Kort, J. 1941, *B.A.N.*, vol. 9, p. 189.
Lindblad, B. 1922, *Ap. J.*, vol. 55, p. 85.
Lohmann, W. 1953, *Z. f. Ap.*, vol. 32, p. 298.
Lundmark, K. 1930, *Pop. Astr.*, vol. 38, p. 26.
Mayall, N. U. 1946, *Ap. J.*, vol. 104, p. 290.
Morgan, W. W. 1956, *P.A.S.P.*, vol. 68, p. 509.
Pease, F. G. 1914, *P.A.S.P.*, vol. 26, p. 204.
Popper, D. M. 1947, *Ap. J.*, vol. 105, p. 204.
Roberts, M. S. 1956, *A.J.*, vol. 61, p. 195.
Rosino, L. 1957, *Asiago Oss. Cont.*, no. 85.
Sandage, A. R. 1953, *A.J.*, vol. 58, p. 61; 1954, *A.J.*, vol. 59, p. 162; 1957a, *Ap. J.*, vol. 125, p. 422; 1957b, *Ap. J.*, vol. 125, p. 435.
Sawyer, H. B. 1953, *D.D.O. Comm.*, no. 34; 1955, *D.D.O. Pub.*, vol. 2, no. 2.
Schwarzschild, M. 1940, *Harv. Circ.*, no. 437; 1954, *A.J.*, vol. 59, p. 273.
Shakhbazian, R. K. 1957, *Russ. Astr. Circ.*, no. 177, p. 11.
Shapley, H. 1915, *Mt. W. Cont.*, no. 116; 1918, *Mt. W. Cont.*, no. 152; 1930, "Star Clusters", Cambridge, p. 45.
Slipher, V. M. 1918, *Pop. Astr.*, vol. 26, p. 8.
Stebbins, J. and Whitford, A. E. 1936, *Ap. J.*, vol. 84, p. 132.
Struve, O. 1955, *Sky and Tel.*, vol. 14, nos. 8, 9.
de Vaucouleurs, G. 1956, *Irish A. J.*, vol. 4, p. 13.
von Weizsäcker, C. F. 1955, *Z. f. Ap.*, vol. 35, p. 252.
Wilson, A. G. 1955, *P.A.S.P.*, vol. 67, p. 27.
Wilson, O. C. and Coffeen, M. 1954, *Ap. J.*, vol. 119, p. 197.

FAST PARABOLOIDAL MIRRORS

By Peter G. White
Toronto Centre

In these days of elegant catadioptric telescopes and cameras, the fast uncorrected paraboloidal mirror is rather uncommon, except in large telescopes. Yet a mirror of this type will perform as well as a Maksutov, Schmidt, or small lens reflector-corrector system for most *visual* work, and it is my purpose here to show why. I also entertain the hope that some amateurs may be persuaded to build telescopes of this type instead of the usual f/8.

An amateur finds, on completing his first 6-inch f/8 telescope, that he has an instrument which is just on the verge of portability. It can be carried with difficulty, but won't fit in his car without some dis-assembling. It may or may not go through his back door in one piece. In short, it is just too big to encourage frequent use. What amateur has not considered building a catadioptric system with its fast primary mirror and consequent short tube? But on investigating the difficulties and expense involved in making a correcting device, he usually decides to stick to paraboloidal mirrors. He also decides that he must use relatively slow focal ratios, because he has heard or read that the field of a short focus paraboloid is prohibitively small.

While it is quite true that the good field of a paraboloidal mirror decreases rapidly with focal ratio, it is equally true that an f/8 telescope wastes most of its good field when used visually, regardless of the eyepiece fitted. I believe that an f/4 mirror, for example, is more suitable for the average amateur than an f/8, and with modern testing methods he will have little if any more difficulty in making it.

The good field of a paraboloid (i.e. the field in which the comatic flare does not exceed the diffraction disk) can be given as approximately $F^2/25$, from data given by Baker (1953), where F is the focal ratio. This can be combined with the usual equation for primary image size to give

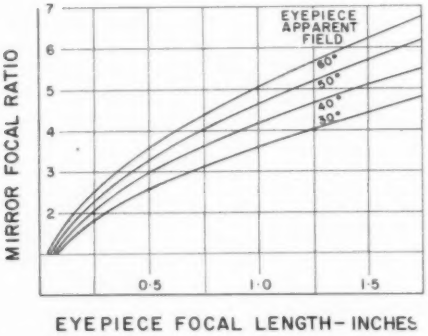
$$a = \frac{F^2}{f_o} \times \frac{57.3}{25},$$

where a is the angular field in degrees, and f_o is the mirror focal length in inches. The real field of an eyepiece is $A\ f_e/f_o$, where A is the apparent eyepiece field in degrees and f_e is the equivalent focal length in inches.

From the above we can show that the focal ratio of a mirror whose good field matches the field of a particular eyepiece is

$$F = 0.66 \sqrt{A f_e}.$$

A mirror with a focal ratio less than F will give comatic star images near the edge of the field; one with a focal ratio greater than F will be wasting part of its field. The figure is a graph which gives the mirror



Graph for matching the fields of a paraboloidal mirror and an eyepiece.

focal ratio necessary to match a given eyepiece. To use it, select the eyepiece with the widest field and longest focal length which you wish to use with your mirror. Then read from the graph the mirror focal ratio to match this eyepiece.

What conclusions can we draw from all this? It will be seen from the graph that an f/3.9 mirror can be used with a 35° eyepiece with 1-inch e.f.l. A paraboloidal 6-inch f/4 mirror can therefore be used successfully with eyepieces giving a range of powers from about 25 (1-inch eyepiece) to 150 (4mm. eyepiece). In addition, the field of view for each of these powers will be exactly the same as with a slower objective mirror. I think most readers will find this surprising. As resolving power depends on aperture alone, it will be the same at f/4 as f/8. For any given power the observer must use a shorter focal length eyepiece with its smaller eye relief and possibly higher cost, but this is a small price to pay for the convenience of having a telescope of only half the usual length.

Most amateur work is visual and the short focus paraboloid is best for visual rather than photographic work. For photography, although the primary image is much brighter and the exposure time shorter, this is achieved at the expense of a large reduction in primary image field.

Here then is where the short focus paraboloid earned its bad reputation—its good field is too small for most photographic work. This reputation has been unjustly carried over to visual use.

A few years ago, most of the above would have been of academic interest only; the accurate figuring of an f/4 mirror was an extremely difficult job for the average amateur not equipped with a good optical flat. In using the Foucault test the allowable error in reading the knife-edge position is 0.010 inches (Jones, 1957). However, a null test described by Dall (1953) can be used and at a cost for all equipment of under one dollar!

A null test for a paraboloid is one in which the knife-edge test gives an even darkening all over the face of the mirror, when the mirror has the proper figure. The Foucault test is a null test for a sphere. By using Dall's test a worker can figure a mirror without the necessity of taking measurements of the knife-edge position and thereby eliminate the main obstacle to making a good short focus mirror.

At this point it might be of interest to try to ascertain why low focal ratios have never attained popularity. In the 18th and 19th centuries, short focal length eyepieces were of poor quality. The owner of a small telescope had to rely on a long focal length objective mirror to obtain reasonable magnifications. During the great upsurge of amateur telescope making of the past 20 or 30 years, this type of telescope seems to have been neglected. This is probably due to the combined effects of its undeserved reputation and the difficulty of figuring.

Summing up then, it is quite reasonable to expect excellent performance from an f/4 mirror (or even an f/3 if the type of eyepiece is chosen carefully) without any correcting devices, although the field will be too small for most photographic work. This type of telescope lends itself especially well to amateur use because of its portability, even with quite large apertures, and it can be made without any undue effort.

References

Baker, J. C. 1953, *Amateur Telescope Making*, Book 3.

Dall, H. E. 1953, *Amateur Telescope Making*, Book 3 and *J. Brit. Ast. Assoc.*, vol. 57, no. 5.

Jones, R. T. 1957, *Sky and Telescope*, vol. 16, p. 548.

CANADIAN SCIENTISTS REPORT-XI

THE DUAL-RATE MOON-POSITION CAMERA

By Malcolm M. Thomson
Dominion Observatory, Ottawa, Ontario

The moon has for many years been considered an ideal celestial object for the purpose of measuring long arcs across the earth, establishing differences in longitude, and determining the size of both the lunar orbit and the earth. Observations of total solar eclipses for many centuries, and more recently the excellent work by amateur astronomers in timing occultations, have pointed valuable material for checking the theory of the moon. Eclipses and occultations are limited however, both in frequency and occurrence and place of observation so that there have been continuous efforts to develop methods which do not have these disadvantages. Several early suggestions were made to apply the method of photographing the moon against a background of stars, two of which were demonstrated to be practical. H. H. Turner (1903) of Oxford tested the use of a focal plane shutter which slowly scanned the image of the moon while stars were registered as dots in a guided exposure of 10 to 15 minutes. At Harvard from 1911 to 1917, A. S. King secured results by taking a snapshot of the moon at the centre of a ten-minute guided exposure. His results were reduced at Princeton by H. N. Russell. (1913, 1916).

A more practicable recent application of the photographic method has been achieved by Wm. Markowitz (1954, 1957) of the U.S. Naval Observatory. Since 1952 the method has been under test, and various improvements incorprated, with the result that the position to the moon may be determined in right ascension and declination with an accuracy previously unobtainable.

U.T.2. The present method of timekeeping is dependent on the rotation of the earth on its axis, and on a catalogue of stars whose positions are well determined. The stars may be considered as markers on the face of the celestial clock, each star representing a definite hour, minute and second. Transit instruments (figure 1a and 1b) capable of scanning only

along the plane of the meridian are used to note the exact time of passage of stars across the meridian. The observed time is sidereal which differs from mean solar in the ratio 366.2422 to 365.2422. Universal Time, now called U.T. (or U.T.0), is derived directly from star transits. Two

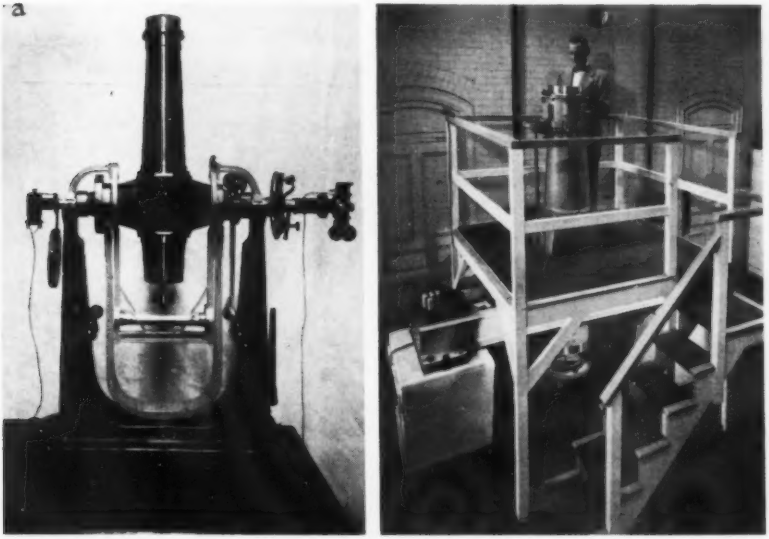


Fig. 1—(a) Broken type Cooke transit telescope capable of observing stars in transit anywhere along the visible meridian. (b) The photographic zenith telescope is restricted to stars which transit close to the zenith. Because of its increased precision, it has been generally adopted by observatories that provide a time service.

small corrections now have to be applied. One is due to the wandering of the earth's poles of rotation, which is a small measurable quantity amounting to a maximum of 0.^{s}030 at the latitude of Ottawa. U.T.0 plus polar wandering correction yields U.T.1. There is in addition an annual fluctuation in the rate of the earth's rotation. It is detectable by reason of modern precise timekeepers and amounts to a maximum of 0.^{s}030. U.T.1 plus the correction for annual fluctuation yields U.T.2, which is highly uniform, and which is used to assess the performance of frequency standards.

U.T.2 is thus dependent for its determination upon the measured rate of rotation of the earth. Such irregularities in rotation as are readily detectable are applied to the observations to give a very uniform time.

But there are small changes in rate of rotation which are not detectable immediately. They enter directly into the determination of U.T.2 and hence affect the unit of time, the second. They also affect the assessment of precise frequency standards. Since the new caesium standards are apparently capable of a precision of the order of a part in 10^{10} (Essen and Parry, 1957) and since the small irregularities in the earth's rotation may be a few parts in 10^8, clearly some more precise astronomical method for observing time must be sought.

Ephemeris Time. The motions of the various members of the solar system have been observed with increasing precision from the days of antiquity. In particular the motion of the earth about the sun and the motion of the moon about the earth are sufficiently well known that, assuming time to be uniform, the relative positions of the earth, sun, and moon can be predicted with a high degree of precision. Conversely, an observation of either the sun or the moon made from the earth against the background of the stars will indicate a precise instant in this uniform time which is called Ephemeris Time or E.T. The moon is by far the preferable object to observe because stars may be seen right alongside, and because its motion through the stars is thirteen times faster than that of the sun (0.″55 as opposed to 0.″04 in one second).

An observation of the moon is made according to U.T.2. The observed longitude of the moon represents an ephemeris time which differs from U.T.2 by Δ T where

$$\Delta T = \text{E.T.} - \text{U.T.2.}$$

Hence, when ΔT is known and applied to U.T.2, E.T. becomes known. The information leading to a precise knowledge of ΔT is to be derived during the I.G.Y. from 20 moon cameras located around the world.

The Theory of the Moon. The use of the moon in this I.G.Y. programme is made possible because of two recent programmes, the lunar theory and the lunar profile. The theory of the moon, as developed from a lifetime of study by E. W. Brown, was at first reduced to tabular form by the use of desk computers. Certain approximations to the intricate theory were required to make the reductions possible. Now electronic computation has been applied to the theory of the moon's motion so that a new set of moon tables has been produced in strict accord with gravitational theory. Tabulation is to 0.ˢ001 and 0.″01. This ephemeris of the moon is considered satisfactory for the next several decades. Yale University, the

U.S. Naval Observatory, and the Watson Computing Laboratory co-operated in this monumental task.

Lunar Profile. Coupled with the improved lunar ephemeris is a further improvement made possible by a study of lunar profiles. In figure 2, two views of the moon are shown, the first two days before and the other two

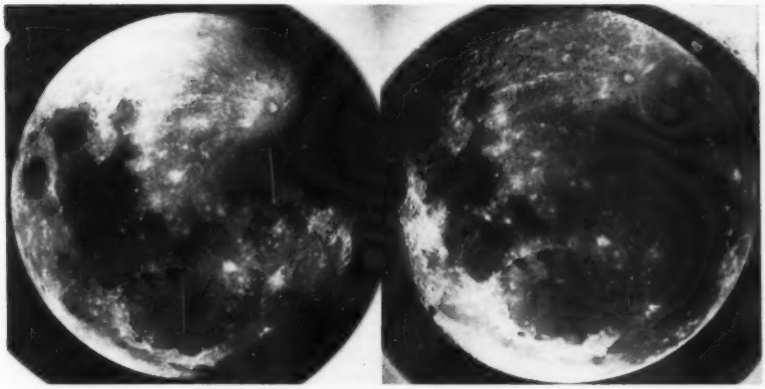


Fig. 2–Two views of the moon secured with the Ottawa dual-rate moon camera, *left*, October 6, *right*, October 10, 1957, each two days away from full moon. North is to the bottom as seen with an inverting telescope. Note the rugged nature of the lunar surface. The change in phase means that opposite limbs of the moon must be used in the two photographs in order to determine the lunar centre of gravity.

days after full moon. Even a casual glance will indicate both the rugged nature of the lunar surface and its consequent effect on the lunar profile, and also the change in profile caused by change of phase in the four day interval. Mr. C. B. Watts of the U.S. Naval Observatory has made an extensive survey of lunar profiles. The result, to be published in 1958, will enable the profile on any particular date to be related to the same centre of gravity.

The Moon Camera. The moon camera is designed to hold the moon fixed against the background of stars for a 10- to 20-second exposure. A circular filter (figures 3a and 3b) intercepts the image of the moon reducing its brightness 1,000-fold. At the same time the filter is made to tilt at a uniform speed causing the image of the moon to be displaced backwards exactly the amount of its forward motion through the stars. Also the axis of the filter is adjustable to place it at right angles to the

apparent motion of the moon. Timing is secured by means of a contact arm attached to the tilting filter, and the epoch of the exposure is the instant that the filter is parallel to the emulsion when there is no relative shift of the moon.

The second motor is to drive the plate at uniform stellar speed, thus

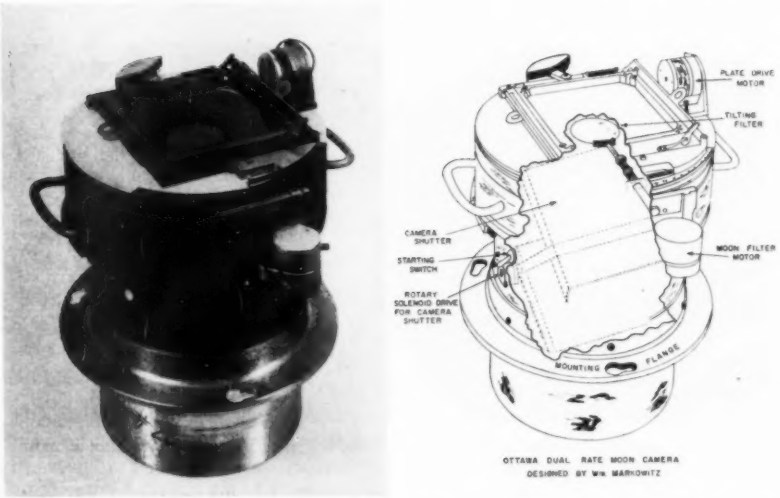


FIG. 3—The dual-rate moon camera designed by Wm. Markowitz of the U.S. Naval Observatory, Washington, D.C. The Ottawa camera is identical with the twenty built for the I.G.Y. but adapted to the 225-inch focal length of the Ottawa 15-inch equatorial telescope.

dispensing with telescope drive. This feature is not required at Ottawa because the 15-inch equatorial has been equipped with sidereal drive derived from a standard frequency oscillator.

A switch on the side of the camera sets in motion a 30-second cycle of operation. During this interval a rotary solenoid causes the shutter to open for either 10 or 20 seconds. The longer interval may be used with faster plates when the moon is in partial phase. The glare attendant on full moon requires slower plates and shorter exposure time. As the tilting filter is rotated the driving arm provides the electrical timing contacts which are fed through a thyratron switch to a drum chronograph.

Errors. It would appear from experience gained at Washington that accidental errors involved in the moon position project during the I.G.Y. will be small owing to the number of participating institutions. Systematic errors may be more important. Four measuring machines are to be located

at four centres including Washington. Systematic errors in the measuring engine screws will be reduced by careful measurement of four reticles which will be exchanged among the measuring centres. Also special star fields will be photographed by all twenty observing stations to compare flexure and any other peculiarities of individual telescopes. It is expected that the observations will have a probable error of about 0."15 in each co-ordinate, and that the measurements will have a probable error of less than 0.2 micron.

From the standpoint of frequency, it is hoped that the I.G.Y. programme will result in the establishment of E.T. with a precision of about 1 part in 10^9. This precision will be increased as observations of the moon and the determination of E.T. are extended over an interval of several years.

The 15-inch Equatorial. The 15-inch equatorial (focal length 225 inches) has been adapted to the moon programme. The eye end has been redesigned to provide a breech of 9 inches internal diameter in place of the former 4 inches. A calibrated focusing screw insures positive focusing and a return to a previous setting. The moon camera terminates in a flange with three slotted bolt holes which enables the camera to be readily returned to the telescope with the same orientation. Figure 4

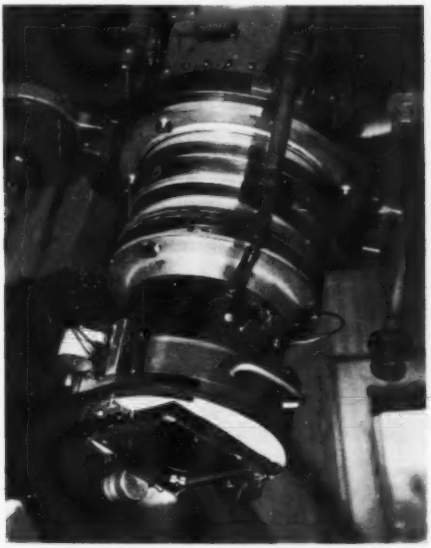


Fig. 4—The moon camera attached to the 15-inch equatorial telescope of the Dominion Observatory.

shows the moon camera attached to the telescope. The present objective is designed for use in the visual range. A yellow filter Schott GG-11 intercepts the blue light, while the plates, which are 103G or IIG, are insensitive to the red. The moon camera thus makes use of a narrow region of the visual spectrum and is focused to the light bordering on 5000 A.

Operational Technique. Four plates are exposed in succession, the camera being rotated through 180° between each exposure. Development for 4 minutes in D19 at 68° F. may be shortened if one suspects the glare of the moon to be excessive. Each plate is carefully marked with serial number, date, time, and observer. The star field is identified, and the plate is sent to the measuring centre, the Ottawa plates being sent to Washington. A typical Ottawa plate is shown in figure 5, in which five stars are identified.

Fig. 5—A picture of the new moon secured with 20-second exposure on type 103 G Eastman Kodak plate. North is to the top, as seen with the naked eye. The stars have been accentuated for the purpose of reproduction. Each star is identified with its B.D. catalogue number, its magnitude and spectral type as listed in the Yale Zone Catalogue. Light from the moon has been intercepted by the tilting filter.

Geophysical Implications. While the determination of E.T. is the most important information for time services, the moon camera programme has geophysical implications of great importance. Each photograph of the moon establishes a position line in space between the camera, the moon, and the background of stars. Two such position lines obtained with a wide separation in hour angle serves to identify the x, y, z location of the camera with respect to the centre of the earth. The distance between any two cameras, measured across the surface of the earth would serve to establish the scale of distances in metres. Twenty co-operating stations will provide information concerning the size and shape of the earth.

The effective use of the moon camera is achieved only with the continued determination of U.T.2. ΔT is a quantity which varies because of small changes in the earth's speed of rotation. Hence the accurate determination of ΔT will provide direct astronomical evidence as to the size and occurrance of these same changes in earth rotation.

General. The Dominion Observatory is co-operating in several phases of the I.G.Y. The unit of time, which is basic in so many scientific experiments, has been the peculiar object of observation and study at observatories equipped for meridian astronomy. The new dual rate moon camera is not restricted to a meridian instrument, but on the contrary involves observations at widely differing hour angles. The Ottawa 15-inch equatorial is excellent for just such a programme, and the Ottawa-Washington base line is expected to provide a vital link in the discussions.

References

Essen and Parry, 1957. *Phil. Trans. Roy Soc.* (London), Series A, vol. 250, p. 45.
Markowitz, W. 1954, *A.J.*, vol. 52. p. 69.
Markowitz, W. 1957. Rept. of study group 9, XI Gen. Assembly I.U.G.G., Toronto.
Russell, H. N., 1913, *Ann. Har. Coll. Obs.*, vol. 72, p. 1.
Russell, H. N., 1916, *Ann Har. Coll. Obs.*, vol. 76, p. 127.
Turner, H. H., 1903, *R.A.S., M.N.*, vol. 64, p. 19.

MINUTES OF THE ANNUAL MEETING OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA*

The Annual Meeting was held at 8:15 p.m., Friday, March 28, 1958, in the Mills Memorial Library Theatre, McMaster University, Hamilton, Ontario; the President, Dr. Helen S. Hogg in the chair. Minutes of the annual meeting of February 8, 1957, were adopted as printed in the JOURNAL.

A standing roll call indicated members were present from the Centres at Halifax, Montreal, Ottawa, Toronto, Hamilton, London and Winnipeg, and the total attendance, including guests, was slightly over 200. New on the roll call was the Calgary Centre, which had been admitted as a new centre by action of the National Council three hours before.

Dr. Hogg displayed a bronze reproduction of the Society's great seal which had been cast as a gift to Mr. E. J. A. Kennedy in recognition of his many years of service in the office of National Secretary. She regretted that he could not be present to accept it.

Mr. J. E. Kennedy, the acting Secretary, in presenting the National Secretary's report noted (1) that the Annual Meeting was being held outside Toronto for the first time in the Society's long history; (2) that two Honorary Members—Dr. S. A. Mitchell and Dr. Joel Stebbins—had been elected by Council, and (3) that several prominent and active members had died during the year. The President then called upon the members to stand in silence for a minute's tribute to the memory of the "departed colleagues" who included Professor Henry Norris Russell, an Honorary Member; John Robinette Collins, a former national secretary and past-president of the Toronto Centre whose membership dated back to 1893, and Major E. R. Gibson, the vice-president of the Victoria Centre.

In his report as National Treasurer, Mr. J. H. Horning noted the Society had ended the year with a surplus and had been able to reduce the mortgage debt on the new Headquarters property in Toronto to $10,500.

Miss Ruth J. Northcott, the Editor, reported on the Society's publications, and Dr. J. B. Oke, the Librarian, stated that a record 350 books and periodicals had been lent out to members during 1957.

The reports were duly received and are printed in this JOURNAL.

In her "President's Remarks", Dr. Hogg pointed out that 1957 had been a momentous year for astronomy. Launching of the first earth satellites had made the science an experimental one, rather than just observational.

*See photograph on page 144 of this JOURNAL.

The year had brought two naked-eye comets, the brightest since Halley's of 1910. There had been unusual solar activity and astronomers throughout the world were taking an active part in the varied aspects of the International Geophysical Year programme. Dr. Hogg expressed the hope that the "Sputnik Age" would be reflected in increased activity and accomplishments by the Society.

Prof. W. J. McCallion expressed the thanks of the Society to the National Officers for their faithful service.

The Rev. Norman Green, President of the Hamilton Centre, took the chair while Dr. Hogg delivered the Presidential Address on "Globular Star Clusters", the text of which is printed in this JOURNAL. At the conclusion of this address, Mr. H. B. Fox expressed the thanks of the audience and Mr. O. J. Paton presented a bouquet of roses to Dr. Hogg on behalf of the National Council.

Miss Northcott reported for the Scrutineers that 452 ballots had been returned by mail; the elected Officers and Council are printed on page 135.

Dr. J. F. Heard expressed the appreciation of the visiting members to the Hamilton Centre as hosts of the day and noted particularly the fine arrangements which included a demonstration of the Spitz planetarium, a dinner at which Dr. G. P. Gilmour, president of McMaster University, was speaker, and a reception planned for the conclusion of the present meeting. The meeting was then adjourned.

FREDERIC L. TROYER, *Recorder.*

REPORT OF THE PRESIDENT

It has always been considered the duty of the president of this Society to present an address, rather than to make a report. However, the year just ended, 1957, is such a momentous landmark from the standpoint of astronomy that I would like to make a few remarks about it.

For in that year, astronomy became an experimental science, and not just an observational one. When the first Sputnik went into orbit on October 4, a new era began on our planet. Not in the four thousand million years previous had any directed activity on this earth been able to hurl a body so high and so fast that it began to circle the earth as a satellite.

Not merely have our man-made moons and the start of the International Geophysical Year made 1957 a landmark, but other important events occurred as well. The two brightest comets visible here since Halley's in 1910, gave beauty to our skies. One of them, Comet Arend-Roland, became a celestial swordfish. It distinguished itself by sending out a spike towards the sun contrary to the usual direction of material from a comet in the direction opposite to the sun. The sun itself staged some remarkable behaviour, in a very high maximum of the sun-spot cycle and a greater abundance of spots in high latitudes than ever previously seen.

One such spot at mean latitude 38° S. actually lived through one rotation of the sun, something never before observed for a high latitude spot.

A remarkable achievement of 1957 was the sending of a 12-inch telescope by unmanned balloon to 80,000 feet to take the finest pictures of the sun's surface ever obtained. Project Stratoscope, under the direction of Professor Martin Schwarzschild, showed that the granules on the sun's surface are much smaller than earlier supposed, 150 miles in diameter. This project is of special interest to members of our Society, because our Gold Medallist of 1956, Donald Morton, now a graduate student at Princeton, assisted in it.

With all this activity, it was befitting that our Society stir itself too. You will remember that several years ago the Greenwich Observatory moved from Greenwich to Herstmonceux, though the prime meridian of the world was thoughtfully left behind at Greenwich. In a similar way our Society has this year moved the site of our annual meeting from Toronto, where it has always been held since the birth of our Society, to Hamilton, where we are enjoying the gracious hospitality of the Hamilton Centre and McMaster University. We too have left our prime meridian behind, namely our headquarters building in Toronto. And we have present at this meeting, representatives from more of our Centres than have ever attended one annual meeting before.

We hope that the Sputnik Age will be reflected in increased activity and increased accomplishment for our Society.

HELEN S. HOGG, *President.*

REPORT OF THE NATIONAL SECRETARY

The Society has already profited from the new constitution adopted in 1957, in the flexibility of the annual meeting, and financially from the increase in membership fees. We are constantly looking for new ways in which we can strengthen the Society and assist astronomy.

There have been two National Council meetings held in 1957 and a total of four since the last Annual meeting. The Executive Committee met on six occasions in 1957 and three times so far in 1958. Both the National Council and Executive have been very fortunate in having the energy and efficiency in the chairmanship of our President, Dr. Helen S. Hogg.

The particulars of the purchase of the property at 252 College Street were given in detail last year. This building provides the Society with adequate facilities for its activities, and as the report of the Treasurer shows, the investment has been an excellent one. The payments of the principal are substantially reducing the mortgage; the income from rentals is profitable. The property committee is to be commended for its faithful work, and mention should be made of the supervision of Mr. Carl Reinhardt in the detailed operation of this property.

The Society has lost a number of valued members through death, and in particular the passing of Mr. J. R. Collins of the Toronto Centre should be noted. He had the greatest number of years of continuous membership of anyone in the Society. We regret also the untimely passing of the Vice-President of the Victoria Centre, Major E. R. Gibson, in a mountain-climbing accident, and the death of a distinguished honorary member, Professor Henry Norris Russell of Princeton.

Miss Ruth Northcott as Editor of the Society's publications has introduced changes

in the cover and format of the Observer's Handbook and Journal during the past year. The press run of 6,000 copies of the Handbook was virtually all sold in 1957. The appointment of Dr. Leonard Searle as Assistant Editor has helped in the workload of editing the Journal. The Executive is pleased that the Society's publications receive favourable comment from other organizations.

The President has devoted time to the preparation of a pamphlet outlining the aims and operations of the National Society, now with Centres in six of the ten provinces of Canada. This will be published shortly.

A number of new ventures have been initiated in 1957. For the first time in the history of our society the annual meeting is being held outside Toronto—in Hamilton, upon invitation of the Hamilton Centre and McMaster University. We hope that the success of this venture may encourage other Centres to be host for future anuual meetings.

The Montreal Centre has urged the extension of the Annual meeting to a second day to allow time for members of the Society to present papers. The endorsement of this proposal for 1959 indicates another stage has been reached in the growth of our organization.

The production of the Insignia of the Society in a form which can be worn by members has been another achievement of the past year.

The number of Honorary Members was increased to thirteen by the election of two outstanding astronomers at the National Council meeting on January 15th, 1958, Drs. S. A. Mitchell and Joel Stebbins. Two honorary members have died since the last such election in 1956. The 1958 paid-up membership of the Society stands at 1,500; of this total approximately 300 are members-at-large, unattached to any Centre.

Neither the Chant medal, nor the Society's gold medal was awarded in 1957.

The reports of the Secretaries of the 13 Centres summarize the activities carried out with success in the year just ended. There is every reason to expect growth of membership and expansion of the Society to include new Centres in the year ahead. All Centres should be aware of the need of satisfying the interest of the juniors by giving sound direction to their activities.

The Executive is very gratified to have representatives from seven Centres attend this Annual Meeting, an all-time record for the Society. Limited financial assistance was provided by the National Office for two of these Centres, Winnipeg and Halifax. It is hoped that this initial start on assistance may be augmented next year.

The Executive Secretary for the past four years, Mrs. Dorothy Williamson, resigned in October of 1957. The Society has expressed its appreciation to Mrs. Williamson for her years of devoted service.

Miss Mary McCarthy has been appointed as the new Executive Secretary; a sincere welcome is extended to her in assuming these duties.

E. J. A. Kennedy, *National Secretary.*

REPORT OF THE LIBRARIAN

During 1957 the library was used to a considerably greater extent than in previous years; the number of books and periodicals borrowed was about 350. This should be compared with 200 in 1956 and 70 in 1955. It is hoped that this trend will continue in the coming years. It should be drawn to the attention of members that books may be borrowed by mail.

A number of new books were added to the library during the year. Some of those were acquired through a donation of Mr. Carl Reinhardt. In addition the library receives regularly 44 periodicals, and publications from 60 observatories. Nearly all of the periodicals are received in exchange for the JOURNAL.

In the course of the year a great many back issues and volumes of the JOURNAL were sold. The revenue from these was $500. Orders and requests for prices are still coming in quite regularly.

J. B. OKE, *Librarian.*

REPORTS OF SECRETARIES OF CENTRES

HALIFAX CENTRE

The following regular meetings were held in the Planetarium Room of the Nova Scotia Museum of Science.

January 29—R. L. Baglow: "Nuclear Fission in Stars", accompanied by a film on the sun.
February 26—Leonard Carrigan: "The Zodiacal Constellations", illustrated by a planetarium showing.
March 26—Showing of the film "Our Mister Sun", loaned through the courtesy of the Telephone Companies of Canada.
April 30—R. L. Baglow: "The Moon", illustrated by slides.
May 28—Leonard Carrigan: "The Purpose and Organization of the I.G.Y."
June 25—R. L. Baglow: "The Moon".
September 24—Annual meeting for the election of officers.
October 29—Rev. M. W. Burke-Gaffney, S. J.: "Highlights of the Eleventh Assembly of the International Union of Geodesy and Geophysics".
November 26—Showing of the film, "The Strange Case of the Cosmic Rays", loaned through the courtesy of the Telephone Companies of Canada.

The average attendance for the year was 23 members.

An outdoor star night was held in July and was attended by about two hundred and fifty people.

D. NAUGLER, *Secretary.*

CENTRE DE QUEBEC

La plupart des officiels se trouvant engagés dans l'organisation du projet d'observatoire, notre Centre a dû mettre de côté ses réunions générales mensuelles. En fait, il n'y en eut qu'une seule, la réunion générale annuelle du 10 janvier 1958, au cours de laquelle on fit l'élection d'un nouveau Bureau. Pour la circonstance, la causerie a été faite par M. Paul-H. Nadeau, qui traita le sujet suivant: "Réflexions en marge des succès soviétiques—Déficiencies de notre Education Nationale".

Le 8 février, notre collègue M. Maurice Drolet se voyait décerner, à Toronto, la médaille Chant pour l'année 1956. A son retour, il était l'objet d'une réception à l'Hôtel de Ville et fut invité par M. le Maire à signer le Livre d'or de la Cité de Québec. M. le Président Dumont, après avoir présenté le récipiendaire de façon élogieuse, exposa devant le Conseil Municipal quelques aspects du projet d'observatoire dont notre Centre s'est fait le promoteur.

Lors du lancement du premier satellite artificiel, notre spécialiste en électronique, M. Félix Edge, organisait une station de repérage par radio, dans la banlieu de

Québec. Nous avons pu ainsi profiter de renseignements de première main sur la marche du satellite.

Le 6 décembre, les constructeurs de télescopes de la région se réunissaient à l'observatoire. Il fut convenu de répéter ces réunions périodiquement, et de jeter les bases d'une section permanente, dès que les conditions le permettront.

L'observatoire temporaire de la tour Martello est demeuré ouvert au public durant une heure, chaque soir de temps convenable. D'autre part l'observatoire est spécialement à la disposition des membres toute la soirée du samedi.

En décembre, l'Académie des Sciences publiait sa quatorzième édition de l'Alamach-Graphique. Cette fois, la part de notre Centre dans la préparation technique du tableau a été plus grande que les années précédentes.

PAUL-H. NADEAU, *Le Secrétaire.*

MONTREAL CENTRE

The Montreal Centre finally established its observatory during the 1955–56 session. The year 1955–56 was therefore a year of promise, while 1956–57 was a year of fulfilment.

During this session, members were offered a wealth of activities seldom equalled by amateur astronomical societies. Members could attend a course on Elementary Astronomy or lectures by eminent astronomers. They could join one or more of the numerous observing teams gathered in the observatory round our able director of observations. The use of the observatory increased until the Centre found it necessary to amend its constitution and create a new office—The Assistant Director of Observations.

An important change was made in our system of lectures this year. In the past, members of the Centre usually gave six lectures on elementary astronomy mainly for the benefit of the beginners. This year, a course of lectures given by one person replaced this, as it was felt that the coherence and unity of a planned course would be more useful to beginners than six lectures on what might be disconnected topics. Miss Williamson gave the course this session, so successfully that it will be repeated in the 1957–58 session.

The lectures by eminent astronomers were all well attended. The Townsend Memorial Lecture was delivered by Dr. R. M. Petrie of the Dominion Astrophysical Observatory, on the subject "Modern Views on Stellar Associations". Dr. A. Vibert Douglas of Queen's University spoke about the Leiden Observatory and the work of Eddington, Dr. Hawkins of Harvard College Observatory introduced us to the new science of "Radio Astronomy". Dr. V. Gaizauskas of the Dominion Observatory, Ottawa, lectured on "Solar Activity", while Dr. Cameron of Chalk River dealt with "New Elements in the Stars". Father Eric O'Connor of Loyola College presented a much discussed lecture on "Relativity for Beginners".

In conjunction with Sir George Williams College, the Montreal Centre acted as host for the 1957 spring meeting of the American Association of Variable Star Observers. This function was a great success, equally enjoyed by members of the Centre and members of the A.A.V.S.O.

The unexpected arrival of two comets and the satellite has given members practice in observation.

In conclusion, 1956–57 has been a year of fulfilment and we confidently look forward to many such years in the future.

CHARLES FOX, *Secretary.*

CENTRE FRANÇAIS DE MONTRÉAL

Au cours de l'année 1957 les membres du centre français de la Société Royale d'Astronomie de Montréal se sont réunis quelque huit en séance régulière.

22 janvier—ils étaient les invités de l'Engineering Institute of Canada pour y voir le film "Our Mister Sun", film en couleurs traitant du système solaire et de la terre. Cette réunion tenait leiu de réunion régulière.

7 fevrier—C'est le centre anglais de la société qui nous invitait à entendre le Dr. R. Petrie directeur du Dominion Astrophysical Observatory de Royal Oak B.C. et président de la société; il avait intitulé sa conférence "Modern Views on Stellar Clusters".

26 fevrier—Un de nos membres M. Lucien Coallier nous présentait un ouvrage sur la Sélénographie lequel est accompagné de croquis et de projections nous faisant connaitre les reliefs de la surface de la lune.

25 mars—M. Jean Asselin, Ing. P. explique aux membres la lecture du graphique du ciel publié annuellement et gracieusement par l'Académie des Sciences du Maryland, et aussi de l'utilisation du manuel de la société, le "Handbook".

29 avril—Les membres se réunissent au local habituel pour mettre au point les préparatifs de la célébration du 10e anniversaire du Centre Français de Montréal. M. Jean Asselin y présente en plus use causerie sur les comètes et particulièrement sur la comète Arend-Rolland, alors visible dans notre ciel.

18 mai—Le Centre Français célèbre le 10eme anniversaire de sa fordation. Il est reçu par le maire de Montréal au restaurant Hélène de Champlain à l'Ile Ste-Hélène. Après un plantureux destin de nombreux fiscours, les membres pouvaient observer le ciel dans des appareils que plusieurs membres avaient installés à proximité. De nombreux invités et délégations des centres de Montréal et de Québec étaient présents à cette celebration.

17 juin—Le Professeur René Robert de l'Ecole Polytechnique de Montréal présente un travail qui a pour titre "La mesure de la vitesse de la lumière".

21 octobre—Assemblée générale annuelle. On y fait la lecture des rapports financiers et des activités de l'année. On procède à l'élection du counseil pour l'anée 1957–58. La soirée se termine par la présentation du film "Our Mister Sun".

Tout l'été les membres on pu observer le ciel au cours de différentes réunions en plein air, dirigées par MM. Adélard Rousseau et Jean Asselin.

En plus des réunions régulières, le bureau de direction s'est réuni deux fois en 1957.

FLEURANGE LAFOREST, *Secrétaire-tresorier.*

OTTAWA CENTRE

The Council met in May and October to plan the public lectures and discuss other business of the Centre. A revised Constitution was prepared and adopted at the Annual Meeting.

Public lectures were held as follows:

January 15—L. R. O. Storey, Ph.D: "Whistlers".

February 22—E. R. Niblett, M.A.: "The Main Geomagnetic Field.

March 22—Leonard Searle, Ph.D.: "The Chemistry of Cosmic Material".

April 25—Observers' Group: "The Moon, our Nearest Neighbour". Participants were Cameron, Stairs, Mott, Griffin and Orr.

September 6—Annual Sky Party; adverse weather conditions prevented observations.

October 9—Joint meeting with The Museum Society. The Russian film "The Sikhote—Alin Meteor Crater" was shown following an introduction of it by P. M. Millman, Ph.D. Several members of the Russian Embassy staff were in attendance.

November 19—Joint meeting with the Institute of Radio Engineers. R. W. Tanner, M.A.: "Optical Sighting of Sputnik"; C. O. Hines, Ph.D.: "Tracking and Prediction of Sputnik by Radio Means".

December 3—Annual Dinner Meeting and election of officers; A. E. Covington, M.A.: "Astrology".

The membership of the Centre is now 110 (including 10 Life Members). A number of the members of the Centre were able to observe Comet Arend-Roland 1956h in May and Comet Mrkos 1957d in July and August.

The Observers' Group, under the leadership of Col. John Stairs held a programme of field trips and regular meetings at which there were discussions of current astronomical events and telescope making. Members of this group were alerted to watch for the first Sputnik in the early hours of the morning; some were rewarded by obtaining excellent photographs of the satellite.

L. G. MILLER, *Secretary.*

TORONTO CENTRE

The Toronto Centre held 13 regular meetings during 1957, two of them being joint meetings with the Royal Canadian Institute on Saturday evenings. Other activities included three "Summer Star Nights" on the University of Toronto campus; three "Sky-Gazing Parties" held in city parks, with showings of astronomical films in addition to telescopic observing; the usual telescope display each clear or partly clear night during the 14-day Canadian National Exhibition (August 23 to September 7); a display of telescope making techniques and completed instruments at the Canadian Handyman Show (November 1–9) arranged by the Telescope Makers Group.

A 12th edition of the "Sky Facts" folder was printed and distributed to the public at the various "extra-mural" events, donatel by the *Toronto Daily Star.*

Speakers and subjects at the regular meetings were:

January 15—Bart J. Bok, Ph.D., Commonwealth Observatory of Australia: "Radio Signals from the Milky Way".
January 29—Motion picture film, "Our Mr. Sun", courtesy of The Bell Telephone Co. of Canada.
February 19—William R. Hossack, Ph.D.: "Earth's Man-Made Moons".
March 5—Leonard Searle, Ph.D.: "Chemistry of the Stars".
March 16—Peter M. Millman, Ph.D., Ottawa: "Domes Against the Sky". (A joint meeting with the Royal Canadian Institute.)
April 2—Amateur Astronomers at Work. Talks and demonstrations by members of the Telescope Makers Group and Observations and Study Group.
April 16—A. Vibert Douglas, Ph.D., Queen's University: "Arthur Stanley Eddington —The Man and His Work in Retrospect".
October 1—Charles L. Seeger, Ph.D., Leiden Observatory: "Galactic Halos".
October 15—Members' Open House at David Dunlap Observatory.
October 29—A. Lloyd Morgan, M.D.: "The Eye as an Astronomical Instrument".
November 26—J. J. Nassau, Ph.D., Cleveland, Ohio: "Galileo, the Star Gazer with the First Telescope".
December 14—Helen S. Hogg, Ph.D.: "Stars that Travel Together". (A joint meeting with the Royal Canadian Institute.)

Good use was made of the basement meeting room at 252 College Street, the Telescope Makers Group holding 20 regular meetings there, with an average attendance of more than 25, and the Observation and Study group nine meetings. Members of the Telescope Makers Group provided telescopes at the public nights on campus, in the parks, at the Canadian National Exhibition, and at every open Saturday night at the David Dunlap Observatory. This group completed sixteen telescopes, repaired three of the Society's telescopes, and made star diagonals for two, and had 50 mirrors in process at the end of the year. The Observation and Study Group held 10 regular meetings ranging from talks on the 1956 opposition of Mars to observation of the transit of Mercury.

Several meteor observing nights were held during the year in connection with the I.G.Y. programme, and many members made auroral reports. The two bright comets of the year and the artificial satellites were frequently observed by Group members, the comets photographed and the "Sputnik's" radio signal tape recorded. The Lunar Section under direction of R. V. Ramsay also carried on its own observing programme and held monthly meetings.

The informal coffee parties in the Society's Reading Room, having proved very popular and an incentive for members to make better use of the Library, were continued during the year and held after most of the regular Tuesday meetings.

The Centre had the pleasure of a visit in late summer of Mr. Frank M. Bateson, a member who maintains his own private observatory in the Cook Islands in the South Pacific.

It is with deep regret that we record the death, on September 19, of John Robinette Collins, a member of the Society for 65 years and a past president of the Centre.

FREDERIC L. TROYER, *Secretary.*

HAMILTON CENTRE

During the year 1957, eight regular meetings were held in the Physical Sciences Buildings, McMaster University; one Council meeting was held to arrange for the two field nights and discuss the business of the Centre. The total membership is 79 (including three life members and three student members).

January 3—J. H. Sled, Phm.B.: "Cosmic Rays"; W. J. Sled, B.A.: "Galaxies".
February 7—W. S. Mallory, M.A.: "Our System of Stars, Our Galaxy" and "How to Use the Observer's Handbook"; W. J. McCallion, M.A.: "The Distances of Stars and How These are Found".
March 7—E. Langley: "Mars"; O. J. Paton: "Eclipses".
April 4—J. M. Winger: "The Mysteries of the Moon"; T. M. Norton: "Life History and Achievements of Robert Hooke".
May 2—W. K. Harris: "Stellar History"; J. G. Craig, B.Sc.: "The Electronic Photographing of Stars".
July 3 and 4—Field Nights.
October 3—J. M. Winger: "Meteor and Auroral Observing"; W. J. McCallion, M.A.: "What is Between the Stars".
November 7—W. J. McCallion, M.A.: "Elements of Astronomy" (1); J. M. Winger: "Rockets and Satellites".
December 5—W. J. McCallion, M.A.: "Elements of Astronomy". (2); N. Green, B.A., L.Th.: "Stars and Constellations".

GEORGE MURCHIE, *Secretary-Treasurer.*

LONDON CENTRE

There were seven regular meetings during 1957. All meetings were held in the Hume Cronyn Memorial Observatory of the University of Western Ontario. Observations were made with the ten-inch refractor when weather permitted. The meetings were as follows:

February 8—Ruby Ebisuzaki, B.Sc.: "The Interstellar Medium".
March 22—R. J. Uffen, Ph.D.: "The Earth's Interior"; W. H. Adamson, M.A.: "Handbook Study"; H. R. Kingston, Ph.D.: "Determining the Beginning of Spring".
April 26—W. G. Graham: "Telescope Making"; A. J. Watt, Ph.D.: "A Transit of Mercury".
June 28—W. H. Wehlau, Ph.D.: "Auroral and Meteor Observing Techniques"; H. R. Kingston, Ph.D.: "Handbook Study". Poor weather prevented observation of the Draconid Meteor Shower.

September 28—Public Observation Night.
October 7—J. B. Oke, Ph.D.: "The Evolution of Stars and Galaxies".
November 22—R. W. Nicholls, Ph.D.: "Meteor Physics in the Atmosphere and in the Laboratory"; G. R. Magee, Ph.D.: "Handbook Study".
December 13—R. W. Packer, M.A.: "Modern Developments in Weather Forecasting". Annual Meeting.

W. H. WEHLAU, *Secretary.*

WINDSOR CENTRE

Nine regular meetings and one executive meeting were held during 1957. The average attendance was 45.

January 8—Lawrence H. Aller, Ph.D., University of Michigan: "Experimental Approach to Astrophysics"; L. Huneault: "Current Events".
February 12—Robert S. Richardson, Ph.D., Mount Wilson Observatory: "When We Land on Mars".
March 12—Roger Thibert, Assumption University: "Formation of Elements in the Stars".
April 9—George Carhard, Pontiac, Michigan: "Man and the Stars"; D. C. Bawtenheimer: "Current Events".
May 14—At the home of Mr. and Mrs. D. C. Bawtenheimer. Adverse weather conditions prevented observations.
September 10—Film—"Our Mr. Sun"; courtesy of The Bell Telephone Company. D. C. Bawtenheimer: "Current Events".
October 8—A demonstration of telescope making was presented by E. W. Keith. D. C. Bawtenheimer: "Current Events".
November 12—Annual Meeting.

P. C. HAWKES, *Secretary.*

WINNIPEG CENTRE

Five regular meetings were held in the Library Theatre at the Fort Garry campus of the University of Manitoba. The speakers and topics were:

January 25—R. J. Lockhart, B.A.: "Astronomy and Poetry"; W. Jonsson: Book review *Earth Satellites* by Patrick Moore.
February 14—R. M. Petrie, Ph.D.: "Associations of Stars", illustrated with slides.
March 14—"Our Mr. Sun", a 60-minute colour film distributed by The Bell Telephone Company was introduced by D. R. P. Coats.
April 24—Two unusual scientific recordings were played: "Earthquakes" and "Sounds from the Ionosphere"; R. J. Lockhart, B.A.: "Geophysical Years Past and Present".
November 27—The CBC "Pacific 13" film on the Dominion Astrophysical Observatory was shown. A panel discussion was held on Sputniks I and II with J. Scatliff, M.D., T. D. Cairns and J. L. Green participating. Some material prepared by D. R. P. Coats was also included.

A series of programmes combining music and astronomy entitled "The Music of the Spheres" was held on the campus of the University of Manitoba during the week of July 29th. Noon-hour lectures and evening observations were held while the summer school was in session for the second consecutive year.

An observation night was held on October 25th for the public on the roof of the Science Building on the University campus.

T. D. CAIRNS, *Secretary.*

VANCOUVER CENTRE

There were seven regular meeting of the Centre in 1957, all in the Physics Building of the University of British Columbia. There were three meetings of the Council during the year. Twenty-nine new members joined the Centre and one was lost

through death. The attendance varied between 253 (November 12) and 27. The speakers were:

January 8—J. B. Holdcroft, M.E.I.C.: "Other Worlds".
February 12—A. W. Mackenzie: "Time and the Precession of the Equinoxes".
March 12—Norman Barton, M.A.: "The Use of Film in the Study of Astronomy".
April 9—P. Gould: "Planets and Vancouver's 'Sun' "; R. J. Clark: "Origin of the Earth's Crust".
October 8—V. J. Okulitch: "Astronomical Photography for the Amateur".
November 12—F. K. Bowers, J. R. H. Dempster, A. K. Goodacre: "The Russian Artificial Satellites".
December 10—R. W. Stewart, Ph.D.: "The Clouds in the Galaxy".

There were tests or demonstrations at five of the six meetings of the Telescope Section. The average attendance was about 20. There are approximately twenty telescopes now under construction.

The centre set up telescopes on the University grounds during June, July and August. An exhibit was arranged by the President and Mr. McGrath at the Pacific National Exhibition.

The Annual Dinner was held at the Faculty Club on December 10th with 34 in attendance. The Annual Meeting was held in the Physics building after the Dinner.

The Centre is again greatly indebted to the University and to Dr. Shrum for the use of the Physics Building.

R. J. Clark, *Secretary.*

VICTORIA CENTRE

Six regular meetings of the Victoria Centre were held at Victoria College. We are indebted for the facilities so generously made available to us.

January 9—Graham J. Odgers, Ph.D.: "Variable Stars".
February 6—Bart J. Bok, Ph.D.: "Radio Sources in the Milky Way".
March 13—Anne B. Underhill, Ph.D.: "Living Stars".
April 10—Professor John L. Climenhaga: "The Red Giant Stars".
October 9—Paul W. Merrill, Ph.D: "From Atoms to Galaxies".
November 13—Rev. M. F. McCarthy, S. J., Ph.D.: "Stellar Populations".

A booth in the hobbies section at the Annual Exhibition of the local Junior Chamber of Commerce was one activity of the Centre. Meteor and auroral observing groups were formed under the chairmanship of R. S. Evans to participate in the I.G.Y. programme.

The annual *Summer Evenings with the Stars* were not held. Instead, nineteen members attended a course in astronomy presented at the Victoria College Summer Session. Several members assisted Dr. R. M. Petrie and Dr. Anne B. Underhill by making their telescopes available for observing periods after the lectures.

Under the able guidance of J. Muir, N. Hutchings and C. Wyatt, a number of student members are making telescopes. The Council is making a concerted effort to bring more members into active participation by organizing groups in telescope making, astronomical photography, constellation lore, observing and elementary computation. We are looking forward to the reports of these groups next spring.

Membership increased from 86 to 90 during the year and now stands at 89, comprised of 1 Honorary Life Member, 8 Life Members, 62 Members and 18 Student Members.

In August, the Victoria Centre suffered a very great loss through the tragic death of Major E. R. Gibson, First Vice-President, who was killed in a mountaineering accident.

D. H. Andrews, *Secretary-Treasurer.*

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
STATEMENT OF INCOME AND EXPENDITURES
FOR YEAR ENDED DECEMBER 31, 1957

GENERAL ACCOUNT

INCOME

Membership fees	$4,621.80	
Grants from Government of Canada and Province of Ontario	4,500.00	
Members' donations and miscellaneous contributions	771.05	
Publications (sales and subscriptions)	6,213.06	
Advertising revenue	995.65	
GROSS INCOME		$17,101.56

EXPENDITURES

Printing of publications	$10,793.13	
Grants to R.A.S.C. Centres	88.00	
Office salaries	3,678.90	
Rents (including rental allowance for Society's office)	622.30	
Stationery, printing and office supplies	435.10	
Postage and express (less amounts charged)	238.81	
General expenses (including medals and awards)	199.73	
Library expenses	33.94	
Telephone	121.22	
Bank charges and foreign exchange	162.06	
Provision for doubtful accounts	155.02	
Depreciation on furniture and equipment	245.00	
TOTAL EXPENDITURES		16,773.21
NET OPERATING INCOME		$328.35

BUILDING ACCOUNT

INCOME

Rents received	$2,705.00	
Rental allowance for Society's office	600.00	$3,305.00

EXPENDITURES

Taxes	$419.32	
Mortgage interest	752.50	
Fuel	337.50	
Light, gas and water	192.19	
Property maintenance and repairs	95.34	
Insurance	39.04	
Depreciation on building	412.50	2,248.39
NET BUILDING INCOME		$1,056.61

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

BALANCE SHEET — DECEMBER 31, 1957

ASSETS

CURRENT			
Cash on hand and in banks		$10,383.99	
Accounts receivable	$1,689.50		
Less: Allowance for doubtful accounts	111.42	1,578.08	
Remittances due from R.A.S.C. Centres		369.50	
Unexpired insurance and prepaid expenses		136.71	
			$12,468.28
FIXED			
Land—252 College Street—at cost		$17,000.00	
Building—252 College Street—at cost	$16,500.00		
Less: Accumulated depreciation	412.50	16,087.50	
Furniture and equipment—at cost	$2,450.00		
Less: Accumulated depreciation	245.00	2,205.00	
Library—Nominal value		100.00	35,392.50
			$47,860.78

LIABILITIES

CURRENT		
Outstanding cheques	$247.77	
Accounts payable and accrued charges	4,646.04	$4,893.81
MORTGATE PAYABLE		12,000.00
DEFERRED INCOME		
Membership fees received for 1958 and subsequent years	$1,443.97	
Prepaid subscriptions to Journal and Observer's Handbook	861.98	
Prepaid advertising for 1958 publications	1,222.92	
Advance grant from Government of Canada	3,500.00	
Contributions towards expenses of 1958 annual meeting	100.00	7,128.87
TOTAL LIABILITIES		$24,022.68

EQUITIES

Surplus (as per statement attached)	$21,596.41	
Life Membership Reserve	2,241.69	23,838.10
		$47,860.78

STATEMENT OF SURPLUS

Balance at December 31, 1956		$20,211.45
Add: Net operating income for year 1957	$328.35	
Net building income for year 1957	1,056.61	1,384.96
Surplus—December 31, 1957		$21,596.41

HELEN S. HOGG, *National President* J. H. HORNING, *National Treasurer*

REPORTS OF TREASURERS OF CENTRES

Receipts	Montreal*	C.F. de Montréal	Ottawa	Toronto	Hamilton
Balance from 1956	$528.11	$177.80	$339.56	$1807.66	$149.06
Membership fees	937.00	150.00	611.00	2006.50	285.00
Donations for N.O.†			10.00	88.50	
Contributions to Centre	109.01	35.00	10.00	135.25	
Rebate from N.O. re 1956			4.00		3.00
Educational activities	43.00		7.25		
Annual dinner			138.25		
Sale of Handbooks, etc.			90.62		17.00
Bank interest	8.69	2.56	5.12		3.82
Income from investments	709.00				
Total	$2334.81	$365.36	$1215.80	$4037.91	$457.88

Disbursements					
Fees remitted to N.O.	$635.00	$102.00	$433.00	$849.00	$192.00
Donations remitted to N.O.			10.00	308.50	
Meetings and lectures	356.44	14.18	50.00	303.98	22.60
Annual dinner			131.62	93.75	
Handbooks			30.00		
Equipment and supplies	275.26	1.01	40.65		2.75
Office and administration expenses	102.61	22.84	54.61	125.00	46.33
General expenses	153.85	21.30	21.66	14.25	49.88
Transferred to special funds	250.00				
Balance carried to 1958	561.65	204.03	444.26	2343.43	144.32
Total	$2334.81	$365.36	$1215.80	$4037.91	$457.88

TORONTO CENTRE SPECIAL PURPOSE FUND

Receipts		Disbursements	
Balance January 1, 1957	$716.99		
Annual grant from C.N.E.	200.00		
Bank interest	76.60	Balance December 31, 1957	$993.59
Totals	$993.59		$993.59

M. Altman, *Treasurer*

*See next page for special accounts and report from Quebec Centre.
†N.O.—National Office.

Receipts	London	Windsor	Winnipeg	Edmonton	Vancouver	Victoria
Balance from 1956	$14.59	$136.62	$121.69	$215.40	$205.67	$ 62.00
Membership fees	210.00	118.00	174.00	134.00	345.00	423.00
Donations for N.O.			2.00			
Contributions to Centre	4.50	5.00				20.00
Rebates from N.O. re 1956	13.00	23.00	1.00	2.00	3.00	18.50
Educational activities						4.50
Annual dinner						118.00
Sale of Handbooks, etc.				2.25	6.34	6.28
Bank interest		4.05		7.84	4.10	0.80
Total	$242.09	$286.67	$298.69	$361.49	$564.11	$653.08
Disbursements						
Fees remitted to N.O.	$140.01	$86.00	$67.45	$92.00	$229.99	$203.34
Donations remitted to N.O.		5.00	2.00			
Meetings and lectures	9.52	20.00	7.50	16.20	4.90	
Annual dinner						118.41
Handbooks				2.25		4.40
Equipment and supplies			23.86	6.40	3.08	
Office and administration expenses	1.18		22.51	3.35	23.00	47.26
General expenses		5.00		2.00	0.55	
Balance carried to 1958	91.38	170.67	175.37	239.29	302.59	279.67
Total	$242.09	$286.67	$298.69	$361.49	$564.11	$653.08

MONTREAL CENTRE OBSERVATORY FUND

Receipts		Disbursements	
Balance from 1956	$2057.55	Repairs to dome track	$323.48
Interest on bonds	3.00	Repairs to building	195.63
Bank interest	25.93	Furniture, fixtures, flowers	94.61
Donations	13.51	Balance carried forward:	
		bonds	100.00
		cash	1387.27
Totals	$2100.99		$2100.99

Frank Baker, *Treasurer*

CENTRE DE QUÉBEC

Recettes		Déboursés	
Solde 1956	$ 84.97	Cotisations	$ 257.33
Subvention provinciale	400.00	Remboursement emprunt	209.88
Subvention provinciale 1958	400.00	Observatoire	421.70
Subvention R.A.S.C.	13.50	Administration	208.35
Cotisations	426.03	Don S.A. Trois-Rivieres	70.00
Divers	7.44	Solde 1957	164.68
	$1331.94		$1331.94

Paul-H. Nadeau, *Le Trésorier*

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
OFFICERS FOR 1958

NATIONAL OFFICERS AND COUNCIL

Honorary President—The Honourable W. J. DUNLOP, D.PAED., Minister of Education for Ontario.
President—HELEN S. HOGG, PH.D., Toronto.
First Vice-President—ANDREW MCKELLAR, PH.D., Victoria.
Second Vice-President—PETER M. MILLMAN, PH.D., Ottawa.
National Secretary—J. E. KENNEDY, M.SC., 252 College Street, Toronto.
National Treasurer—J. H. HORNING, M.A., 252 College Street, Toronto.
Recorder—FREDERIC L. TROYER, Toronto.
Librarian—J. B. OKE, PH.D., Toronto.
Council—Halifax: REV. M. W. BURKE-GAFFNEY; Quebec: PAUL H. NADEAU; Montreal: G. HARPER HALL; Montréal (C.F.): J. R. GRIGNON; Ottawa: J. L. LOCKE; Toronto: MRS. K. M. HEATON; Hamilton: H. B. FOX; London: W. G. GRAHAM; Windsor: ————; Winnipeg: R. J. LOCKHART; Edmonton: E. S. KEEPING; Calgary: ————; Vancouver: G. M. SHRUM; Victoria: R. S. EVANS; the Presidents of the Centres; *Elective Members*: MIRIAM S. BURLAND, Ottawa; A. VIBERT DOUGLAS, Kingston; CARL REINHARDT, Toronto; *Past Presidents*: R. M. PETRIE, Victoria; JOHN F. HEARD, Toronto.

HALIFAX CENTRE

Honorary President—REV. M. W. BURKE-GAFFNEY, S.J.
President—LEONARD CARRIGAN
First Vice-President—M. HIGGINS
Second Vice-President—H. O'SHEA
Secretary—MISS CAROLYN NAFTEL, 74 Henry Street, Halifax.
Librarian—W. A. BRIDGEO, PH.D
Treasurer—DEAN NAUGLER
Council—G. H. DAGLISH, M.D.; ELSIE HAYES; H. SNIDER; and *Past President*: JAMES PAUL.

CENTRE DE QUÉBEC

Patron—MGR. ALPHONSE-MARIE PARENT, P.A., V.G.
Président—J.-ALFRED DUMONT
1er Vice-Président—l'abbé ROSARIO BENOIT
2e Vice-Président—LIONEL-PIERRE PELOQUIN
Secrétaire-trésorier—PAUL-H. NADEAU, 229-Ouest, rue St-Cyrille, Quebec 6.
Director des projets électroniques—FELIX EDGE
Aviseur légal—ARCADIUS DENIS
Conseil—FRANCOIS BABY; l'abbé GASTON BECHARD; CHANOINE G. O. COTE; GERMAIN COUTURE; l'abbé BENOIT DENIS; MICHEL FRANCOEUR; LIONEL GALLICHAN; ROLAND MAINGUY; LLOYD MCWILLIAMS; et les *anciens Présidents*—ALBERT DUBERGER; GEORGES-E. GAGNE; JEAN-CHS MAGNAN et LUCIEN POULIOT.

MONTREAL CENTRE

Honorary President—G. HARPER HALL
President—A. R. MACLENNAN
Honorary Vice-President—A. N. SHAW, PH.D.
Vice-President—T. F. MORRIS, PH.D.
Secretary and Recorder—E. E. BRIDGEN, 6156 Sherbrooke St. West, Montreal 28.
Director of Observations—F. J. DEKINDER
Treasurer—FRANK BAKER
Asst. Director of Observations—MISS I. K. WILLIAMSON
Librarian—C. M. GOOD
Council—G. BARON; W. H. BIRTLES; E. A. EDWARDS; CHARLES FOX, PH.D.; MRS. C. JEFFREY; G. B. MOXON; GORDON PENDER, Q.C.; W. A. WARREN; G. WEDGE; and *Past President*—D. E. DOUGLAS, PH.D.

CENTRE FRANÇAIS DE MONTRÉAL

Président—JEAN ASSELIN, ING.P.
Vice-Président—ROGER BONIN
Secrétaire-trésorier—FLEURANGE LAFOREST, 36 Deslauriers Ave., Ste-Geneviève de Pierrefonds, P.Q.
Rapporteur—GASTON LEBRUN
Bibliothécaire—J. E. GUIMONT
Directeur des Observations—JEAN NAUBERT
Conseil—J. A. BUTEAU; HECTOR COLLETTE; DELISLE GARNEAU; MLLE MARCELLE GAUVREAU; J. R. GRIGNON; J. P. LAVIOLETTE; FR. ROBERT, f.e.c.; ADELARD ROUSSEAU; A. D. TESSIER.

OTTAWA CENTRE

Honorary President—HOYES LLOYD
President—J. E. LILLY
First Vice-President—IAN HALLIDAY
Second Vice-President—J. A. STAIRS
Secretary—V. GAIZAUSKAS, Dominion Observatory, Ottawa.
Recorder—MISS J. STEWART
Treasurer—W. J. MEDD
Council—MRS. IAN HENDERSON; L. G. MILLER; W. L. ORR; J. A. ROTTENBERG; R. W. TANNER.

TORONTO CENTRE

Honorary President—JOHN F. HEARD, PH.D.
President—G. A. COOPER, B.A.SC.
First Vice-President—J. B. OKE, PH.D.
Second Vice-President—R. R. BROADFOOT
Secretary—F. L. TROYER, 53 Woodlawn Avenue East, Toronto 7.
Treasurer—G. MYLAND
Recorder—P. W. LOCKE
Director of Telescope Makers' Group—JESSE KETCHUM,
Director of Observation and Study Group—R. R. BROADFOOT.
Council—J. W. ARTER; D. J. GERRIE, B.A.SC.; MISS K. A. HAMILTON; S. HORTON; M. KALBFLEISCH; M. A. KAMIENSKI; R. V. RAMSAY; C. REINHARDT; K. WAKEFIELD.

HAMILTON CENTRE

Honorary President—W. T. GODDARD, B.S., E.E.
First Vice-President—J. G. CRAIG, B.SC.
President—N. GREEN, B.A., L.TH.
Second Vice-President—S. J. BUNTAIN
Secretary-Treasurer—GEORGE MURCHIE, 77 Fennel Avenue West, Hamilton.
Curator—G. E. CAMPBELL, M.A.
Council—E. E. BOSSENCE; P. EWANICK; W. K. HARRIS; T. L. JOHNSON; E. LANGLEY; E. OSTROSSER; C. PIERSON; F. SCHNEIDER; G. E. SHEPPERD; G. VANSICKLE; J. M. WINGER; B. WISHART.

LONDON CENTRE

Honorary President—H. R. KINGSTON, PH.D.
Vice-President—W. H. ADAMSON, M.A.
President—W. H. WEHLAU, PH.D.
Treasurer—G. R. MAGEE, PH.D
Secretary—R. W. RICHARDSON, B.A., 408 Queen's Avenue, London.
Council—R. MANDEL; R. RUSSELL; H. SCHOENFIELD; F. W. R. TAYLOR, M.A.; A. J. WATT, M.D.

WINDSOR CENTRE

Honorary President—REV. N. J. RUTH, C.S.B., M.A.
Vice-President—L. HUNEAULT
President—EDWARD W. KEITH
Treasurer—WM. J. PERSON, R.I.A.
Secretary—PERCY C. HAWKES, 1855 Kildare Road, Windsor.
Council—D. C. BAWTENHEIMER; C. A. BELL, B.A., Q.C.; H. S. CUNNINGHAM, B.A.; C. B. HALLAM, B.A.; W. A. HARE, B.A.SC.; HENRY LEE; J. W. LOARING; W. J. MITCHELL, B.R.I.; C. MONTROSE, B.A.; G. A. NYBERG; W. L. SWANSON, M.A.; R. G. WARWICK, B.A.

WINNIPEG CENTRE

Honorary President—H. H. SAUNDERSON, PH.D.
First Vice-President—N. W. WILDE
President—J. SCATLIFF, M.D., B.SC.
Second Vice-President—J. L. GREEN
Secretary-Treasurer—T. D. CAIRNS, 924 Waterford Avenue, Winnipeg 9.
Recorder—MISS I. CHRISTIE.
Council—D. R. P. COATS; MRS. E. CRANSTONE; R. J. LOCKHART, B. A.; C. R. PUNSHON; G. L. SADLER; G. M. WISEMAN; W. W. WRIGHT.

EDMONTON CENTRE

President—E. MILTON
Vice-President—J. HARRINGTON
Secretary—D. R. CROSBY, PH.D., University of Alberta, Edmonton.
Treasurer—H. J. MONTGOMERY
Librarian—E. S. KEEPING
Observatory Representative—H. GRAYSON-SMITH, PH.D.
Council—A. DALTON; G. GARLAND; H. A. MACGREGOR; E. PHIBBS; L. V. SMITH.

CALGARY CENTRE

Honorary President—THEO. A. LINK
Vice-President—JAMES F. WRIGHT
President—WALTER H. STILWELL
Treasurer—K. B. MEIKLEJOHN
Secretary—MISS H. L. TH. HOOGERHEIDE, 1726 10th Street S.W., Calgary.
Recorder—MRS. JOAN C. MCFEELY.
Council—J. O. BROWN; ALLAN GIBB; JAMES R. GRAHAM; REV. J. V. HOWEY; TOM W. LAVIOLETTE; E. J. M. MCCULLOUGH; E. M. ROGERS; WALTER R. SCHMITT; MICHAEL STANTON.

VANCOUVER CENTRE

Honorary President—A. M. CROOKER, PH.D.
Vice-President—G. A. MORGAN
President—R. J. CLARK
Treasurer—MRS. C. A. ROGERS
Secretary—T. CLARK, B.C. Research Council, Vancouver 8.
Director of Telescope Section—S. D. SULLIVAN
Asst. Director of Telescope Section—M. H. PARRY
Council—C. W. DEANS, M.SC.; G. E. FROSTRUP; MRS. ELDA GRANT; M. A. MCGRATH; and *Past Presidents*—A. W. MACKENZIE; A. OUTRAM; E. M. PRICE; M. T. SPENCE.

VICTORIA CENTRE

Honorary President—O. M. PRENTICE
First Vice-President—J. A. MUIR
President—NORMAN G. ROGERS
Second Vice-President—J. L. CLIMENHAGA
Secretary-Treasurer—D. H. ANDREWS, Dominion Astrophysical Observatory, Royal Oak.
Recorder—J. L. D. JERVIS
Director of Telescopes—R. PETERS
Librarian—D. C. WYATT
Council—G. R. BALL; E. R. BROWN; G. J. ODGERS; M. C. TRUEMAN; ANNE B. UNDERHILL, PH.D.; F. R. WILLIAMS.

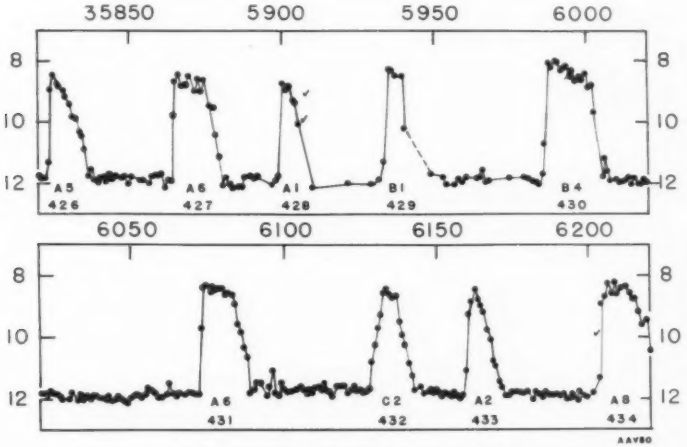
VARIABLE STAR NOTES

By Margaret W. Mayall

The American Association of Variable Star Observers, Cambridge, Mass.

U Geminorum-Type Variables

213843, *SS Cygni*. A variable which is a favourite of observers around the world, SS Cygni was followed with assiduousness throughout the year 1957. We received a total of 1,029 observations of it, made on 295 nights during the year by 47 observers. This includes 161 observations made by 8 members of the Scandinavian Astronomisk Selskab, that were made available to us through the kindness of their director, Mr. Axel V. Nielsen. Maximum No. 429 was caught by only one A.A.V.S.O. observer, Donald Charles, but it was well confirmed by the Scandinavian observers.



MEAN LIGHT CURVE OF SS CYGNI, 1957

The light curve is plotted from daily means; the points determined from 1 to 12 observations each. Seven maxima were observed during the year. and it is quite certain that no maximum was missed.

Table I lists the observed maxima in the same form as used in these Notes in the past. (See this Journal, vol. 51, no. 3, p. 219.) Column 1 is the number of the maximum, numbered consecutively from the first observed maximum in 1896. Following columns are: (2) the type of maximum according to Leon Campbell's classification; (3) Julian Day for magnitude 10.0 on the increasing branch of the light curve; (4) number of days elapsed since the same point at the preceding

TABLE I

1957 MAXIMA OF SS CYGNI

Max. No.	Type	10.0 I J.D.	Diff.	Max. J.D.	Diff.	10.0 D J.D.	Diff.	Max. Mag.
427	A6	2435864	40	2435868	42	2435878	45	8.4
428	A1	5899	35	5901	33	5905	27	8.7
429	B1	5934	35	5936	35	5940	35	8.3
430	B4	5987	53	5990	54	6003	63	8.0
431	A6	6073	86	6075	85	6086	83	8.3
432	C2	6130	57	6133	58	6139	53	8.4
433	A2	6160	30	6163	30	6167	28	8.4

maximum; (5) observed date of maximum; (6) number of days since preceding maximum; (7) Julian Day for magnitude 10.0 on the decreasing branch; (8) days elapsed; and (9) the mean maximum magnitude.

The mean interval between the maxima of 1957 is 48.1 days, somewhat longer than that of the last few years. The mean of all maxima since discovery of SS Cygni is 51.5 days.

060547 *SS Aurigae*. This variable is much fainter than SS Cygni and therefore is not as well observed. Its range in magnitude is 10.5 to 14.5. Observers with large telescopes should make an effort to observe it at every opportunity. Table II is a continuation of a similar table published in these Notes in 1955. (This JOURNAL, vol. 49, no. 3, p. 120.) The mean interval between maxima of SS Aurigae is 54.1 days. Table II shows a sad lack of observations.

TABLE II

OBSERVED MAXIMA OF SS AURIGAE

Max. J.D.	Diff.	Max. Mag.	Width (13th mag.)	Max. J.D.	Diff.	Max. Mag.	Width (13th mag.)
2435158	66	10.6	8 days	5776	43	10.8	10
5237	79	10.7	12	5858	82	10.7	13
5354?	117	11.3?	?	5924	66	10.5	8
5445	91	10.9	12?	5986	62	11.0	?
5500	55	10.5	6?	6044?	58	11.8?	?
5553	53	10.6	15	6140	96	10.5	?
5733	180	10.9?	?	6186	46	11.4	8

0611157 *CZ Orionis*. In spite of the faintness of this variable, 8 maxima were observed in 1957, although some depend on a single observation. Approximate dates and magnitudes are as follows: 5856?, 12.7; 5886, 11.8; 5928, 11.4; 6026?, 11.9; 6087?, 12.3; 6116, 12.2; 6140?, 12.8; 6190?, 12.5.

074922 *U Geminorum*. A wide maximum, number 364, was well observed on 5912, magnitude 8.8, after an interval of 136 days. A narrow maximum on 6205, magnitude 9.1, was provisionally assigned number 367. A single observation of

9.2 by Curtis Anderson on 6074 may have been in the predicted wide maximum number 366.

080362 *SU Ursae Majoris*. More observations with large telescopes are needed of this variable. Its range of brightness is 11.1 to 14.5 and the mean interval between maxima is 17 days. Eleven maxima were observed during the year, although some are questionable, with only one observation. Most of the maxima are very narrow, and are only 2 or 3 days wide at the 13th magnitude. One broad maximum was well observed at 5952, magnitude 11.1. Its curve was 12 days wide at 13th magnitude.

094512 *X Leonis*. The following maxima were observed during 1957: 5858?, 12.5; 5880?, 12.1; 5894?, 12.5; 5900, 12.2; 5917, 12.5; 5930, 12.0; 5948, 12.0; 5981, 12.5; 6012?, 12.1; 6140?, 11.9; and 6195, 12.0. The questioned dates depend on single observations.

184137 *AY Lyrae*. This is another faint variable which needs observation with large telescopes. Its range in magnitude is from about 12.5 to 16, and the mean interval between maxima is 23 days. The following maxima, some questionable, are indicated: 5807?, 14.2; 5962?, 13.2; 5979, 13.6; 5997, 11.8; 6009, 13.8; 6017, 13.3; 6024, 12.9; 6044, 13.1; 6074, 13.4; 6100, 13.6; 6155, 13.4; and 6172, 12.6.

184826 *CY Lyrae*. Two maxima were observed by Thomas Cragg: 6150, 13.7; and 6171, 13.9. The mean range is given as 13 to 16.8, and the mean interval between maxima is 17 days.

195032 *EY Cygni*. No maxima observed during the year.

195109 *UU Aquilae*. Two maxima were observed: 6071, 12.0; and 6124, 11.4.

203501 *AE Aquarii*. This star continues to have frequent and rapid variations of three-fourths of a magnitude and more. Some of the best observed flares are on the following dates: 5983, 6010, 6052, 6073, 6078, 6092, 6096, 6098, 6100, 6110, 6111, 6116, 6120, 6123, 6125, 6128, 6132, 6133, 6139, 6152, 6154, 6156, 6161, 6164, 6165, and 6166. AE Aquarii is seldom constant, but fluctuates 2 or 3 tenths of a magnitude between the stronger flares.

220912 *RU Pegasi*. The maxima of RU Pegasi differ radically in shape and character. It is a difficult star to observe, with a close 12.5 magnitude companion, and there is a large scatter of observations from different observers. It would be valuable for observers to make daily observations whenever the star can be seen. A large telescope is an advantage to separate the companion. The following maxima were observed during 1957: 6048, 10.5 mag., 15 days wide at the median magnitude, 11.5; 6132, 10.1, 10 days wide at 11.5; and 6197, 10.5, 5 days wide at 11.5. The mean range of magnitude is 10.0 to 13.1 and the mean interval between maxima is 70 days.

A.A.V.S.O. Nova Search Report (From George Diedrich, Chairman): Observations of Nova Search Areas were made by the following 10 members for a total of 113 area-nights. Each name is followed by the number of observations made in December, 1957 and then January, 1958: Richard Bates–0, 10; James Breckinridge–3, 0; F. J. DeKinder–15, 0; DeLorne Diedrich–2, 3; George Diedrich–11, 13; G. A. Hall –5, 0; C. C. Rosenfield–0, 2; Jane Shelby–8, 15; James Wesling–10, 12; I. K. Williamson–4, 0.

As is quite obvious by the above, we can use many more observers. Perhaps you'd like to help. Just drop us a line–either to A.A.V.S.O. Headquarters or directly to the Chairman at 653 Weller Road, Elyria, Ohio, U.S.A. We can't predict the next nova, but we keep asking ourselves, "Can it be far off?"

Observations received during January and February 1958: A total of 8,178 observations were received during the two months: in January 4,070 from 59 observers, and in February 4,108 from 51.

Observer	January Var.	January Ests.	February Var.	February Ests.
Adams, R. M.	83	163	79	142
Allin, R.	..	..	3	3
Anderson, C. E.	68	128	79	105
Ball, A. R.	28	47	..	..
Berg, Ray	9	14	..	..
Braune, W.	..	..	39	786
Breckinridge, J.	15	16	5	6
Buckstaff, R. N.	..	..	6	6
Byrd, W.	3	7	..	..
Carlisle, J. H.	1	5	..	..
Cragg, T. A.	168	173	64	64
Darsenius, G.	5	6	8	18
Debono, I. P.	2	2	..	..
Diedrich, DeL.	..	..	4	5
Diedrich, G.	7	10	12	21
Engelkemeir, D.	9	21	9	16
Erpenstein, O. M.	8	8	8	20
Fernald, C. F.	242	385	62	76
Ford, C. B.	142	147	155	158
Garland, G.	9	117	6	133
Gemberling, R. H.	21	36	17	25
Glenn, W. H.	..	..	5	5
Goldenblatt, P. P.	31	31	..	..
Goodsell, J. G.	2	2	4	4
Halbach, E. A.	40	42	..	..
Hartmann, F.	137	139	125	133
Hein, G. J.	1	1	1	4
Hiett, L.	5	11	..	..
Houston, W. S.	7	21	..	..
Kelly, F. J.	11	17	..	..
Knowles, J. H.	16	30	..	..
de Kock, R. P.	124	543	104	413
Kubanoff, J. H.	5	9	..	..
Lacchini, G. B.	14	20	22	81
Lowder, W. M.	14	14	..	..
Magruder, R. S.	..	..	5	8
McPherson, C. A.	15	15	22	26
Melville, E. C.	..	..	11	14
*Miller, J. S.	43	43	3	3
Miller, R. W.	..	..	7	8
Miller, W. A.	24	30	..	..
Montague, A. C.	37	58	37	46
Morgan, F. P.	23	25	20	40
Oravec, E. G.	213	436	198	382
Osypowski, T.	36	37	..	..
Panke, D.	6	9	3	3
Parker, P. O.	46	50	29	35
Pearcy, R. E.	6	6	2	2
Pearlmutter, A. E.	36	73	..	..
Peltier, L. C.	22	113	17	63
Pilcher, F.	..	..	3	3
Price, F. J.	23	40	17	41
Ramthun, D.	3	3	..	..
Renner, C. J.	89	146	61	61
Rizzo, P. V.	22	22	13	17
Robinson, L. J.	15	65	7	42
Rosebrugh, D. W.	16	93	14	78
Rosenfield, C. C.	..	..	3	5
Royer, R.	5	5	3	4
Rudolph, R.	..	..	53	638
Salce, H.	..	..	4	9
Segers, C. L.	20	55	22	34
Sharpless, A. P.	10	10	15	16
Solomon, L.	6	15	51	61
Taboada, D.	208	360	118	159
Tsai, C. H.	21	31	..	..
Valdez, M.	6	125	6	41
Venter, S. C.	..	..	28	41
von Rosenvinge, H.	..	..	6	13
Wallerstein, G.	9	13	..	..
Weitzenhoffer, K.	4	4	..	..
Wend, R. E.	32	40	..	..
Wolfe, J. C.	5	13	..	..

*Plus 1^h UV Cet.

NOTES FROM OBSERVATORIES

Dominion Observatory, Ottawa

Positional Astronomy. Encouraging progress has been made with the new Mirror Transit. The Building has been completed and the mirror and objectives have been mounted. The declination circle is being graduated by Hilger and Watts, while some component parts have yet to be designed and fabricated. Observing conditions during the period covered by this summary have been extremely poor, however the Meridian Circle programmes comprising some 5,300 stars are well in hand. Observations have also been made with the P.Z.T. and broken Cooke telescope for time and latitude determinations. The Markowitz dual rate moon camera, on loan from the U.S. Naval Observatory, was used successfully during three recent lunations. A second ring crystal of Essen design has been installed in a clock vault which formerly housed a Reifler pendulum.

Stellar Physics. The two I.G.Y. programmes, photographic solar flare patrol and meteor observations, have continued though both have been hampered somewhat by poor weather. Plans have been completed for the establishment of a radio observatory in southern British Columbia. The site selected for this observatory is an isolated valley near Penticton, chosen after an extensive survey for its freedom from man-made interference. The contract for the telescope, an equatorially mounted 84-foot parabolic dish, has been let. Construction of the control building and other site development is to begin this summer.

Observations of Sputnik I and Sputnik II have been made whenever conditions were favourable. The observations were a joint effort of Positional Astronomy and Stellar Physics, assisted by staff members from all divisions. Several photographs were obtained. This project is continuing.

Geomagnetism. Results obtained during a 25,850-mile airborne survey of Ontario, Quebec and Hudson Bay have been reduced. Details of design and construction of Observatory instruments were supplied on request to about 100 scientific organizations throughout the world. A nuclear precession magnetometer which provides absolute measurements of total intensity of the magnetic field in terms of an accurately known atomic constant was completed and is operating very satisfactorily. A publica-

tion entitled "Records of Observations at the Magnetic Observatories, Agincourt and Meanook, 1936–1937" has been sent to press.

Gravity. Steady progress in the development of a vibration gravimeter, suitable for measuring gravity at sea or under unstable conditions, has been made. Although auxiliary parts such as computing and recording devices have yet to be built, construction work on the new instrument has advanced to the point where a test of its performance at sea has been possible. During December, in co-operation with the Netherlands Geodetic Commission, comparisons of the gravimeter's performance were made against the Vening-Meinesz pendulums in a submarine near the West Indies. Analysis of these results are now under way.

Seismology. During the period under review the instruments for the new vault at Resolute were installed and calibrated. Complete 3-component installations of long-period and of extra-long-period seismographs are included, and three different short-period vertical instruments are being tested to see which gives the best recording at the location. When this has been decided a matched set of short-period seismographs will be added to the installation. The division is making preparations to record the Ripple Rock blast. The blast will be timed at its source and the waves will be recorded at four permanent stations and more than 15 temporary ones in British Columbia and Alaska.

Personnel. Dr. Beals received one of two gold medals awarded by the Professional Institute of the Public Service of Canada. The citation mentioned his work on interstellar clouds, his studies of emission-line stars and meteorite craters, and his success in raising the standards of the Dominion Observatory to the point where it has become one of the leading institutions in astrophysical and geophysical research. We welcome the following new members to our staff: Mr. J. G. Ryan who replaces H. H. Cooper; Mr. Warren Besserer with Positional Astronomy, and T. C. Bunyan and G. L. Carr at the Meanook Magnetic Observatory. Dr. W. G. B. Britton is a post-doctorate fellow working with the Seismology division. He is from University College of Wales, and is working on the design of an amplifier for a special earthquake recorder.

MIRIAM S. BURLAND

NOTES

The Tenth General Assembly of the I.A.U.

Preparations are being made for Canadian participation in the forthcoming General Assembly of the International Astronomical Union which is to be held this year in Moscow from August 13 to August 20. These preparations are in the hands of the Canadian National Committee for the I.A.U. which consists of a group of astronomers and other scientists to which appointments are made by the Royal Society of Canada, the Royal Astronomical Society of Canada and the Department of Mines and Technical Surveys of the Government of Canada, and which includes also three ex-officio members and three elected members, to make a total of nineteen members. The committee is re-elected every three years. The officers of the present committee are John F. Heard, Chairman, and Donald A. MacRae, Secretary.

Canadian scientists who plan to attend the Moscow Assembly are the following: John Galt, J. L. Locke and M. M. Thomson of the Dominion Observatory, R. M. Petrie, G. J. Odgers and P. E. Argyle of the Dominion Astrophysical Observatory, Helen S. Hogg. Donald A. MacRae and Ruth J. Northcott of the David Dunlap Observatory, P. M. Millman and G. Herzberg of National Research Council, A. Vibert Douglas and G. A. Harrower of Queen's University, A. G. W. Cameron, of Atomic Energy of Canada Limited, and W. A. Russell, a student of the University of Toronto.

Most of these Canadians planning to attend the Assembly are members of Commissions of the I.A.U. As such, they will be considered as guests of the U.S.S.R. Academy of Sciences, and they will be provided with hotels, meals and transportation during their stay in Moscow and in Leningrad. Wives and relatives of these delegates, as well as those who are not members of the I.A.U. will be requested to pay $150.00 for these services.

The programme of the Assembly itself includes meetings of the various Commissions and Sub-commissions under which the I.A.U. operates and also symposia and discussions of such special topics as Artificial Satellites, the Russell-Hertzsprung Diagram, the Rotation of the Earth and Atomic Time Standards, and Nucleogenesis in Stars. The meetings will be held in the new buildings of the Moscow University on Lenin Hills and in the Sternberg Astronomical Institute.

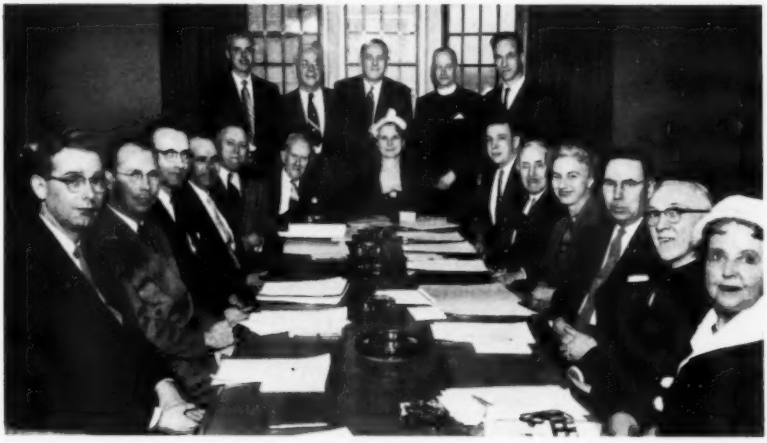
In addition to the I.A.U. Assembly there will be held in Paris from July 30 to August 6, a Symposium on Radio Astronomy sponsored jointly

by the International Scientific Radio Union (U.R.S.I.) and the I.A.U. and also, on August 12 in Moscow, a meeting of the International Council of Scientific Unions Joint Commission on Solar and Terrestrial Relationships.

Plans have been made for participants to visit the Kremlin and various exhibitions, museums and scientific institutions in Moscow. After the Assembly they are invited to spend several days in Leningrad visiting the historic Pulkovo Observatory, the Lomonossov Museum, the Hermitage and other points of interest. Following this, participants may choose from a number of excursions by air which are being offered by "Intourist" at reasonable rates. Among these is one that includes the remains of the famous 13th century observatory of Ulughbeg, in Samarkand.

In the thirty-six years of the existence of the I.A.U., this will be the first of the Assemblies, normally held every three years, to take place in the U.S.S.R. Many astronomers from the thirty-eight participating countries of the I.A.U. are looking forward eagerly to an opportunity to view at first hand the great advances that have been taking place in Soviet astronomy and to be guests of their Russian colleagues.

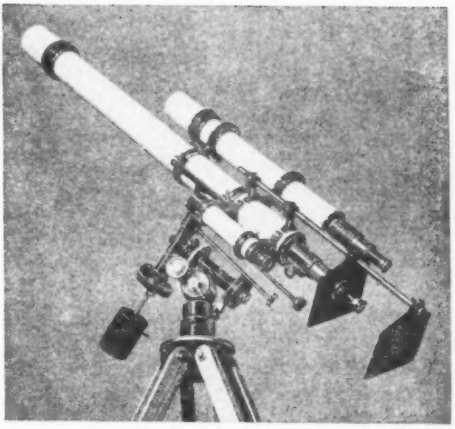
JOHN F. HEARD



National Officers and Centre Representatives at the meeting of the National Council at McMaster University, March 28, 1958. *Seated* (left to right): Prof. J. B. Oke, Librarian; Prof. W. Wehlau, London; Prof. R. J. Lockhart, Winnipeg; Prof. J. F. Heard, Past-Pres.; J. H. Horning, Treas.; Carl Reinhardt; Prof. Helen S. Hogg, Pres.; J. E. Kennedy, Sec.; G. Harper Hall, Montreal; Prof. Ruth J. Northcott, Editor; A. R. MacLennan, Montreal; Rev. M. W. Burke-Gaffney, S.J., Halifax; Mrs. K. M. Heaton, Toronto. *Standing*: Dr. J. L. Locke, Ottawa; W. H. Adamson, London; H. B. Fox, Hamilton; Rev. Norman Green, Hamilton; G. A. Cooper, Toronto.
(*Photograph by Tom Bochsler*)

NOW IN CANADA

Here is the refractor selected by the Canadian and U.S. Armed Forces—and universities throughout the world. Now available here in Canada at the lowest prices ever—with no extra duty or tax charges. Fully guaranteed and serviced by Canada's largest specialists in optical instruments.



2.4" ALTAZIMUTH	—62 mm. coated objective lens, f.l. 900 mm. Four eyepieces 36× to 130×. (150× available at extra cost). Star diagonal, erecting prism system, sunglass. 5× viewfinder telescope. Slow motion controls. Tripod, fitted cabinet ..... $120.
3" ALTAZIMUTH	—3" aperture objective, f.l. 1200 mm. Five eyepieces 48× to 171× (200× and 240× available at extra cost). Large 8× viewfinder, all accessories as above. Complete $245.
3" EQUATORIAL	—optical eqpt. as altazimuth, but additional 200× eyepiece. Has oversize equatorial mounting, with setting circles and verniers for declination and right ascension. Sun projection apparatus included. Complete $375.
4" ALTAZIMUTH	—4" aperture, f.l. 1500 mm. Seven eyepieces 37× to 250× (300× and 375× at extra cost). 10× viewfinder, slow motion controls, all accessories. $450.
4" EQUATORIAL	—as altazimuth, but super focusing mechanism to hold large 60 mm. eyepiece. Giant equatorial mounting and sun projection system. Tripod equipped with shelf and shelf light ..... $685.
4" PHOTO EQUATORIAL	—as above with 77× guide telescope ..... $785.
ROTARY EYEPIECE SELECTOR	—holds six eyepieces, instantly interchangeable $25.00
DOUBLE EYEPIECE	—permits two observers simultaneously $22.50
EYEPIECES	—all coated, o.d. 24.5 mm. (Adapter for 1¼" 35¢ extra). f.l. 25 mm., 18 mm., 12.5 mm. ..... $7.50 fl. 9 mm., 7 mm., 6 mm. ..... $9.00 f.l. 5 mm., 4 mm. Orthoscopic, 40 mm. Kellner $15.00
OBJECTIVE LENSES	—air spaced coated achromats, in cell 3in. $75. 4in. $145. 6in. $750.
ASTRO-CAMERA	—specify for 1¼" or 24.5 mm. eyepieces ..... $75.

W. CARSEN CO.

Twenty-four years specializing in Optical Instruments

W. CARSEN & CO. LTD.

Showroom and Service Lab - 88 Tycos Dr., TORONTO, Can.

Vol. 52, No. 3 JUNE 1958 Whole No. 432

Globular Star Clusters ..... *Helen Sawyer Hogg* 97
Fast Paraboloidal Mirrors ..... *Peter G. White* 109
CANADIAN SCIENTISTS REPORT. XI ..... *Malcolm M. Thomson* 112
ANNUAL MEETING OF THE R.A.S.C.
Minutes of Meeting 120
Report of the President 121
Report of the National Secretary 122
Report of the Librarian 123
Reports of Secretaries of Centres 124
Report of the National Treasurer 131
Reports of Treasurers of Centres 133
Officers and Council for 1958 135
VARIABLE STAR NOTES ..... *Margaret W. Mayall* 137
NOTES FROM OBSERVATORIES 141
NOTES 143

EDITOR—Ruth J. Northcott ASSISTANT EDITOR—Leonard Searle

ASSOCIATE EDITORS—C. S. Beals, R. M. Petrie, A. Thomson

COMMUNICATIONS TO THE EDITORS SHOULD BE ADDRESSED TO

David Dunlap Observatory, Richmond Hill, Ontario

The Society publishes this JOURNAL bi-monthly (February, April, June, August, October and December) and the OBSERVER'S HANDBOOK annually. Single copies of either of these publications are 75 cents.

Membership, which includes the publications, is open to anyone interested in astronomy. Annual dues are $5.00; life membership is $75.00. Application for membership or publications should be made to THE ROYAL ASTRONOMICAL SOCIETY OF CANADA, 252 COLLEGE STREET, TORONTO 2B, ONTARIO.